

The Journal of the
**Utah Academy of
Sciences, Arts, & Letters**

Volume 100 • 2023

**Includes selected and refereed articles from the
2023 Annual Conference
held at The Waterford School
March 18, 2023**

Editor
Kristin L. Kraus

Copyright 2024, Utah Academy of Sciences, Arts, & Letters.
Copyright reverts to authors after publication. Printed in the United States of America by
Brigham Young University Academic Publishing, Provo, Utah. Neither the editors nor the
sponsoring organization assumes responsibility for statements of fact or opinion made by
the contributors.

ISBN-13: 978-0-9988268-7-5
All Rights Reserved

Board of Editors

Arts: Jim Godfrey, Utah Valley University

Biological Science: Daniel Clark, Weber State University

Business: Taowen Le, Weber State University

Education: Nicole Gearing, Utah Valley University

Engineering: Ali Siahpush, Southern Utah University

Kinesiology and Health Sciences: Tracy Fawns, Utah Tech University

Humanities, Philosophy, Foreign Language: Thomas Terry, Utah State University

Language and Literature: Keith Lawrence, Brigham Young University

Physical Sciences: Chris Monson, Southern Utah University

Social Sciences: Emily Putnam, Salt Lake Community College

Posters: Jacque Westover, Utah Valley University

2022-2023 Utah Academy of Sciences, Arts, & Letters Officers

President: Daniel Poole, Salt Lake Community College

President-Elect: Angela Banchero-Kelleher, Utah Valley University

Past President: Rachel Keller, Snow College

Secretary: Colleen Boam, Weber State University

Treasurer: Ryan Boam, Weber State University

Members at Large: Erin O'Brien, Dixie State University; Jonathan Westover, Utah Valley University; H. Laine Berghout, Weber State University

Technology Officer: Vern Hart, Utah Valley University

Finance Committee: Dan Poole, Rachel Keller, Angie Banchero-Kelleher, Jonathan Westover, Lynn Mckell

Cover Photo: “Excerpt from Grade 6 Ancient China Assessment.” See “Social Studies, Culture, and the Utah DLI Program: A Preliminary Didaktik Analysis” by William J. Davis, Jiazhen Yan, Ruohan Gao, and Ziyao Zhou; p. 183.

Utah Academy of Sciences, Arts, and Letters

History: Founded 3 April 1908, the Utah Academy of Sciences was organized "to promote investigations and diffuse knowledge in all areas of science." Beginning in 1923, the Academy started publishing the papers presented in its annual meetings in Proceedings. In June 1933 at the annual meeting, the Academy was enlarged to include arts and letters, and the name was changed to the Utah Academy of Sciences, Arts, and Letters. Articles of incorporation and non-profit organization status were accepted by the Academy membership at the spring meeting in April 1959. In 1977, the name of the journal of the Academy was changed from Proceedings to Encyelia. It became a refereed journal at this time. In the mid 1980s, the scope of the Academy was expanded further to include (1) business, (2) education, (3) engineering, (4) library information and instruction, and (5) health, physical education, and recreation. Beginning with the 1998 issue, the journal became The Journal of the Utah Academy of Sciences, Arts, and Letters.

Annual Meeting: The Academy's annual meetings are normally held in the spring on one of the Utah campuses of higher education. The plenary session is called the Tanner Lecture, endowed by Mr. O.C. Tanner in 1986.

Best Paper Awards: The best paper presented in every division is given a cash award, which is presented at the Academy's "Awards Evening" held the following fall.

Distinguished Service Awards: The Academy recognizes outstanding contributions to teaching and scholarship by means of annual Distinguished Service Awards, alternating every other year between disciplines.

Membership: When the Academy was founded in 1908, membership was by nomination, ratified by the Council, and elected by a "three-fourths votes of members present." Today, the Academy's membership is available by application.

Institutional Members: All Utah institutions of higher education are members of the Utah Academy. The Academy appreciates their patronage.

Publication Policy

The *Journal of the Utah Academy of Sciences, Arts, and Letters* publishes works in all of the fields of study encompassed in the Academy's mission. Papers published in *The Journal of the Utah Academy of Sciences, Arts, and Letters* are drawn from papers presented by members in good standing at the annual conference of the Utah Academy. To qualify for publication, the papers must be recommended through a refereeing system.

Presenters are encouraged to publish their paper in *The Journal of the Utah Academy*. *The Journal's* criteria are that a submission is (1) fresh, meaningful scholarly insight on its subject; (2) readable and well written; and (3) of general interest for an academic readership beyond the author's field.

If you wish your paper to be considered for publication in *The Journal*, please submit a Microsoft Word document to the section editor of the appropriate section by the indicated deadline. Contact information for the section editors is available on the Utah Academy's website (www.utahacademy.org).

The Journal of the Utah Academy is a refereed journal. Editorial responses will be forthcoming after the resumption of school the following fall when referees have returned their comments to the division chairs.

Papers should be between 10 and 20 double-spaced pages. Detailed instructions to authors are available at http://www.utahacademy.org/Instructions_for_Authors.pdf.

Among the bibliographic services listing at Bowker Serials Bibliographies and The Standard Periodical Direction. Indexing and abstracting services that cite articles in the journal include Arts and Humanities Citation Index, Biosciences Information Services, Current Geographical Publicatoin, Chemical Abstracts, Mathematical Reviews, MLA Biography, Sociological Abstracts, Excerpta Botanica, Social Planning, Policy and Development Abstracts, Language and Language Behavior Abstracts, Index to Scientific Technical Proceedings, and Index to Social Sciences, and Humanities Proceedings.

The Journal of the Utah Academy of Sciences, Arts, & Letters 2023

AWARDS

Distinguished Service Award	11
Academy Fellow 2023	12
John and Olga Gardner Prize	13
O.C. Tanner Lecture	14
Honorary Member 2023	16
2022 Best Paper Awards	17

ARTICLES

ARTS

The Relationship Between Music Instruction and Academic Performance	19
Doug Stump ¹ and Laura Peterson ² , ¹ <i>Southern Utah University and</i> ² <i>St. Bonaventure University</i>	
Music Paintings and the Fashioning of an Early Modern Cardinal in Rome: The Case of Cardinal Francesco Maria del Monte	35
Charlotte Tanner Poulton, <i>Utah Valley University</i>	
Sylphs Supporting Sylphs: Confronting Gender Binaries in the Ballet Canon	55
Christa St. John and Jamie A. Johnson, <i>Utah Valley University</i>	

Towards an Invention of Style: Encoding Aspects of the 20th-Century Post-Tonal Tradition for Use in Contemporary Classical Solo Piano Improvisation	71
Evan B. Whitfield	

BIOLOGY

Ditch the Stress: How Mindfulness Activities Affected Perceived Stress, Mood, and Well-being in University Students During the COVID-19 Pandemic	99
Jayden D. Peacock, Dylan T. Gardner, Korina K. Ziegler, Colton G. Davis, and Helen C. Boswell-Taylor, <i>Southern Utah University</i>	

Examination of the highly variable P8 region (trnL-UAA intron) in the genus <i>Equisetum</i>	117
William D. Speer, <i>Salt Lake Community College</i>	

BUSINESS

Comparing Self-Efficacy and Grades of Students in Progressive Accounting Course Levels	143
Jefferson T. Davis, <i>Weber State University</i>	

EDUCATION

Social Studies, Culture, and the Utah DLI Program: A Preliminary Didaktik Analysis	157
William J. Davis, Jiazhen Yan, Ruohan Gao, and Ziyao Zhou, <i>Southern Utah University</i>	

Implementing the Teaching Self Efficacy Development Initiative	183
Todd J. Wentz	

ENGINEERING

- Plane Wall Thermal Radiation Shielding** 201
Tori Thomas, MaryJo Taylor, Michael Forbes, Ali Siahpush,
Southern Utah University
- Natural Convection Over A Heated Vertical Plate** 217
Drew Hatch, Jordan Peterson, Braeden Brown, Jordan Katnik, Ali
Siahpush, *Southern Utah University*
- Boiling and Cavitation Experiment for Engineering
Undergraduate Labs** 235
Savanah Higley and Ali Siahpush, *Southern Utah University*
- Effective Thermal Conductivity of Porous Copper Foam
Saturated with Eicosane Phase-Change Material** 247
MaryJo Taylor and Ali Siahpush, *Southern Utah University*
- Lumped Method Transient Conduction Heat Transfer** 269
Sergio Reyescordova, Kaden Allred, Ethan Arnold, William Miller,
Ali Siahpush, *Southern Utah University*
- Studying Natural Convection Through Melting a Slab of
Ice** 285
Toby McMurray, Manuel Gaspar, Matthew Bayreder, Slater Emery,
and Ali Siahpush, *Southern Utah University*

HUMANITIES, PHILOSOPHY, FOREIGN LANGUAGES

- Make Haste Deliberately: The Historical American
Aversion to Inoculations and Vaccinations with a
Complicit CDC and FDA** 297
Thomas C. Terry, *Utah State University*

PHYSICAL SCIENCES

- Collisional Losses in a Variable Specific-Impulse
Magnetoplasma Rocket** 309
Benjamin Miera and Philip Matheson, *Utah Valley University*

Question Answering on Quantum Computers	321
Thomas Draper, <i>Brigham Young University</i>	

SOCIAL SCIENCES

Staring Into the Abyss: The Origins of Serial Killer Behavior	333
--	------------

Peyton Kosman, *University of Utah*

Sisters in Struggle: The Resistance of Women in Hip Hop	353
--	------------

Theresa A. Martinez, *University of Utah*

Women, Weight, and the Workplace: Exploring the Effects of Economic Weight Bias Against Women	369
--	------------

Niko Dawson, *Weber State University*

ABSTRACTS	385
------------------	------------

DISTINGUISHED SERVICE AWARD 2023

The Distinguished Service Award is given to an academic professional for exceptional service to the higher education community in Utah.

Scott Abbott, PhD

Utah Valley University

Scott Abbott put himself through college working summers as a roughneck on drilling rigs in the San Juan Basin of New Mexico and Colorado. He received his doctorate in German Studies from Princeton University in 1979. After two years as a full-time lecturer at Princeton, he taught for seven years at Vanderbilt University in Nashville. He joined the Department of German and Slavic Languages at Brigham Young University in 1988. With Sam Rushforth, he co-founded a BYU Chapter of the American Association of University Professors to take on academic freedom violations. The Chapter's activism resulted in a powerful censure of the BYU administration by the AAUP

Since 1999, Abbott has been a professor of Integrated Studies, Philosophy and Humanities at Utah Valley University, where he cofounded and has led a UVU chapter of the AAUP. Abbott's books include a study of Freemasonry and the German novel; a book of what he calls "fraternal meditations" written after his brother's death of AIDS; conversations spanning a decade while riding mountain bikes with botanist Sam Rushforth; three works with Serbian novelist Žarko Radaković about travel in the former Yugoslavia and then in war-torn Serbia and Bosnia; an exploration of the meanings of barbed wire with historian Lyn Bennett; and most recently a book of collected essays from the BYU years: *Dwelling in the Promised Land as a Stranger*. He has translated works by Nobel Prize Awardee Peter Handke and botanist Gregor Mendel.

ACADEMY FELLOW 2024

Jonathan H. Westover, PhD

Utah Valley University

Dr. Westover is a professor and chair of Organizational Leadership in the Woodbury School of Business at Utah Valley University, Academic Director of the UVU Center for Social Impact and the UVU SIMLab, and Faculty Fellow for Ethics in Public Life (previously the Associate Director) in the Center for the Study of Ethics. Dr. Westover has been published widely in academic journals, books, and practitioner publications. He is a regular visiting faculty member in other international graduate business programs.

JOHN & OLGA GARDNER PRIZE 2023

The Gardner Prize is awarded annually for exceptional achievement by an academic professional in Utah.

Matthew Wickman, PhD *Brigham Young University*

Dr. Matthew Wickman (PhD, UCLA) began working at BYU in 2000. Trained in literary theory and eighteenth-century British literature, his early work focused primarily on Scottish literary and intellectual history of the eighteenth century and after. Eventually, he held a joint appointment between BYU and the University of Aberdeen, in Scotland.

In 2012, he was named Founding Director of the BYU Humanities Center, and he spent the next decade working with colleagues across BYU's College of Humanities, and with scholars around the world in multiple disciplines, to create initiatives strengthening and promoting humanities scholarship. These initiatives included named lectures, large symposia, research groups, weekly meetings featuring scholarly work in progress, workshops, formal conversations regarding important trends in higher education, venues for student mentoring and research, and wide-ranging forms of community engagement. His term as director of the BYU Humanities Center concluded in 2022, and he assumed a new role as associate coordinator of the BYU Faith and Imagination Institute.

He is the author of more than forty articles and book chapters. Additionally, he has published two monographs—*The Ruins of Experience: Scotland's "Romantick" Highlands and the Birth of the Modern Witness* (2007) and *Literature after Euclid: The Geometric Imagination in the Long Scottish Enlightenment* (2016)—and co-edited the volume *Walter Scott at 250: Looking Forward* (2021). His recent work explores literature's relationship to religious and spiritual experience. His publications on that subject include the book *Life to the Whole Being: The Spiritual Memoir of a Literature Professor* (2022).

O.C. TANNER LECTURE

“From Atomic Bombs to Nuclear Energy”

Sidney Green

University of Utah

Atomic fission bombs developed in WWII led to fusion hydrogen bombs and a world with “assured mutual destruction” nuclear weapons capabilities. U.S. above-ground testing, near to Southern Utah, prior to the above-ground moratorium, was followed by successful underground testing. Commercial applications of nuclear electricity emerged, with the Westinghouse Shippingport, PA, reactor in 1958 the first for the U.S. Despite nuclear incidents at Three Mile Island, Chernobyl, and Fukushima, nuclear energy now provides about 10% of world electricity and 20% of U.S. electricity. Most significantly impacting U.S. nuclear energy are the high costs and long times for large gigawatt power plant construction, leading to small-scale and even micro-scale nuclear plants of fail-safe design being considered. Although not presently with unanimous agreement, safe nuclear energy is an exceedingly important part of the energy transition to reduce carbon emissions.

Sidney Green is founder and President of Enhanced Production, Inc., and has an appointment as a Research Professor in Mechanical Engineering at the University of Utah. He is a founder and past President/CEO of TerraTek, Inc., an engineering firm acquired by Schlumberger in 2006. He has published many papers, holds multiple patents, and has given many invited presentations. He has served as director for various companies, served on government committees and university advisory boards, and testified at congressional hearings. He has served on a number of National Research Council/National Academies committees. Mr. Green has a BS and MS in Mechanical Engineering. He attended the University of Pennsylvania graduate school, and he received the degree of Engineer from Stanford University in Engineering Mechanics in 1964. He has received the Outstanding Engineer award for the State of Utah, Entrepreneur of the Year from the Mountain West Venture Group, Professional Engineer Award from the Missouri Univ. of Science and Technology, and Honorary Alumni Award from the University of Utah. He is a past member of the Greater Salt Lake Chamber of Commerce Board of Governors, he is a Fellow of the American Rock Mechanics

Association, and is chair of the Utah Academy of Engineering and Science. He lives in Salt Lake City with his wife of 62 years and is a member of the National Academy of Engineering.

HONORARY MEMBER 2024

Angela Dunn, MD, MPH

Salt Lake County Health Department

Prior to becoming health officer for Salt Lake County and executive director of Salt Lake County Health Department, Dr. Angela C. Dunn served as state epidemiologist for the Utah Department of Health and as an epidemic intelligence service officer for the U.S. Centers for Disease Control and Prevention, where she responded to the 2014–2016 Ebola epidemic in West Africa.

Dr. Dunn received her medical degree from the University of Miami Miller School of Medicine and completed her residency training in general preventive medicine and public health at the University of California, San Diego. She also holds a Master of Public Health from San Diego State University and a B.A. in international relations from Brown University.

Dr. Dunn lives in Salt Lake City with her husband and two sons. They love exploring the outdoors together year-round.

2023 BEST PAPER AWARDS

Arts

Sylphs Supporting Sylphs

Christa St. John, Jamie Johnson

Utah Valley University

Biological Sciences

Ditch the Stress: How Mindfulness Activities Affected Perceived Stress, Mood, and Well-being in University Students During the COVID-19 Pandemic

Jayden D. Peacock, Dylan T. Gardner, Korina K. Ziegler, Colton

G. Davis, Helen C. Boswell-Taylor

Southern Utah University

Engineering

Boiling and Cavitation Experiment for Engineering Undergraduate Labs

Savanah Higley

Southern Utah University

Physical Sciences

Collisional Losses in a Variable Specific-Impulse Magnetoplasma Rocket

Benjamin Miera, Philip Matheson

Utah Valley University

Physical Sciences

Women, Weight, and the Workplace: Exploring the Effects of Economic Weight Bias Against Women

Niko Dawson

Weber State University

The Relationship Between Music Instruction and Academic Performance

Doug Stump¹ and Laura Peterson²

¹Southern Utah University and ²St. Bonaventure University

Abstract

With states placing an ever-increasing emphasis on mandated test scores and school administrators emphasizing data-driven decisions, it is critical to understand current research on the relationship between music instruction and academic performance and how best to apply these studies in making policy and curriculum changes. Because so many school districts consider cutting music programs when faced with budget constraints, this paper advocates for music as an essential part of the curriculum. This review of current studies demonstrates the relationship between music instruction and overall academic performance and intelligence, mathematics, language learning, acquisition and reading, brain function and cognition, and student well-being. Maintaining music instruction provides clear academic and developmental benefits toward meeting state-mandated performance goals while leveling the academic challenges for students of low socioeconomic and disadvantaged groups.

The trend in American education toward external academic performance accountability through high-stakes, state-mandated standardized testing has placed a high degree of focus on funding what may be referred to as core academic subjects (Miller & Coen, 1994, Kenna & Russell, 2015). These mandates often require schools to hit program and assessment benchmarks but without additional state funding, leading many administrators to reduce allocation of funds to music education and other programs (Abril & Gault, 2008). Despite the rhetoric about the importance of (and increasing funding for) mandated core academic subjects, the research consistently demonstrates that if you teach a child to play a musical instrument, you increase the chances that the child performs at a higher level in reading, math, and other areas.

The relationship between music instruction and academic performance has been a topic of empirical research for decades. Early research in this area was based on the anecdotal or intuitive idea that students who play musical instruments (including participation in some form of choir or band) tended to perform at high levels in academic areas. Whereas studies in the earlier part of the 20th century examined the relationships between music instruction and intelligence (Costa-Giomi, 2012), it was during the second half of the century when the focus turned toward causality. Examples of this shift are studies that investigated the possible relationships between regions of the brain stimulated by music and music learning as the development of spatial reasoning, and thereby academic performance in mathematics and some sciences (Graziano et al 1999; Rauscher & Zupan, 2000). The purpose of this paper is to provide a review of current studies that have emerged regarding the relationship between music learning and academic performance. The aim is to examine the ways these studies address more refined and specific relationships between music instruction and academic performance, while providing educational policymakers and administrators with the data needed to make good policy and curriculum decisions. This paper reviews current studies in the following areas of focus: overall academic performance and intelligence, mathematics, language learning, acquisition and reading, brain function and cognition, and student well-being.

Overall Academic Performance and Intelligence

Research that aims to demonstrate a relationship between music instruction and general academic performance has continued to expand in recent studies. Cabanac et al (2013) studied Canadian secondary students aged 14 to 17 years enrolled in an International Baccalaureate program. The results of the study showed that each year the mean grades

of students that chose to stay in music instruction were higher than those who had not chosen music as their elective course. This trend was true regardless of the topic of the course, and the difference in mean grades was statistically significant. Bilhartz et al (1999) examined the relationship between cognitive development and music instruction in children aged four to six years, with one group receiving a 30-week music curriculum and the second group receiving no music instruction. The group of children receiving music instruction demonstrated significant increases in test results. In a study by Schlaug et al (2005), researchers compared children aged 9–11 years participating in instrument instruction with students of the same ages receiving no instrument instruction. Students involved in music instruction performed significantly better than those in the control group in several WISC-III subtest areas (musical audiation, left-hand index finger tapping rate, and vocabulary). These students also demonstrated improved scores with phonemic awareness.

Studies by Holochwost et al (2017), and Gouzousasis et al (2007), and demonstrated that groups of students with music instruction scored higher on standardized testing for language skills and math and higher in English language arts and math courses and also exhibited higher performance on executive function assessments. Several studies by Schellenberg (2004) addressed the relationship between keyboard or vocal instruction and increased IQ.

Duration of Music Instruction

Although some research compares test scores across grade levels at one time, many studies were longitudinal (Miksza, 2007; Hallam & Rogers, 2016, Wetter et al 2009), demonstrating that students who participated in music instruction had a significantly higher academic performance over time, even when socioeconomic status was factored in. In one such study, Young et al (2013) examined the relationship between academic achievement and arts participation. Participation in the arts was subdivided into two groups: students with access to musical instruments at home and students who participated in unspecified after-school arts activities. A total of 2339 students aged 11 and 12 years were surveyed over a 10-year period. Students who had access to musical instruments at home demonstrated a significantly positive relationship between music instruction and academic achievement.

Mathematics

Early research on the relationship between music instruction and mathematics examined several specific aspects of math acquisition.

Bahna-James (1991) examined the correlation of the grades of secondary school students in music theory and math classes. Another study by Klinedinst (1991) examined teacher evaluation of instrumental instruction and scholastic achievement for elementary school students. Both of these earlier studies revealed a variety of significant relationships between mathematics achievement and music performance, including between sight-singing and arithmetic, algebra, and geometry; between pitch and arithmetic; and between tonal relationships and arithmetic and algebra. Other studies (Eisner, 1998; Catterall et al 1999) demonstrated relationships between music instruction and mathematics scores.

In more recent studies, Baker (2012) compared eighth-grade test scores between students who received performance-based music and visual arts instruction and students who did not. The research demonstrated a significant difference between these groups, with students enrolled in music instruction scoring higher than those who were not. Similarly, Deere (2010) compared the reading and math scores of fourth- and eighth-grade students in Tennessee, with one group of students in a school system with a music program and one group of students in a school system without a music program. The researcher used state test data from 2008–2009, showing that students with a music education program had higher state test scores in both reading and math. Helmrich (2010) examined test scores from over 6000 students. These findings also showed that students enrolled in formal instrumental or choral music instruction during middle school had higher test scores than those students who experienced neither. The differences were statistically significant, even when factoring in demographic data such as race.

Catterall et al (1999) examined several factors in learning music that seem to be connected to mathematics. This study described a relationship between understanding three aspects of music notation—time, rhythm, and pitch—and mathematical reasoning. Additionally, as concepts the relationships between notes within scales are abstract and difficult to conceptualize, but playing notes on a musical instrument created a concrete way to understand this relationship. The results of the study demonstrated that math proficiency—as reflected in higher standardized test scores—increased over time with learning a musical instrument.

Language Acquisition

In the same way that music instruction and math share key learning concepts, music instruction also relates directly to language acquisition

and phonological awareness. Music employs a wide range of processing mechanisms such as encoding, memory, attention, and sequencing just as in language. Primary areas of research address the connection between music instruction and language acquisition and verbal memory, the development of spoken language, general memory, brain plasticity, and speech segmentation.

Acquisition and Phonological Awareness

Several studies, such as those by Patscheke et al (2016), and Vidal et al (2018), have demonstrated the connection between music instruction and language acquisition, phonological awareness, and verbal memory. Studies by Degé and Schwarzer (2011) and Patscheke et al (2016) used similar testing methods to determine the relationship between music instruction and phonological awareness.

François et al (2013) examined speech segmentation and phonological awareness with 24 eight-year-olds chosen to participate in a two-year study. Participants were divided into a music group and a painting group and, over the course of the study, were tested on their ability to recognize meaningless words excerpted from a stream of nonsense syllables. The quantitative findings demonstrated that participants with music training improved speech segmentation abilities, whereas those that painted did not. A similar but more recent study by Vidal et al (2019) examined 44 children between three and four years of age. Children trained in music developed greater skills in speech segmentation, dividing both real and artificial words into syllables, and in synthesizing the syllables of both words and artificial words. Several other older studies also demonstrate an association between music and language skills.

Reading

Corrigall and Trainor (2011) found a substantial association between the length of music training and reading comprehension in a study using students aged six to nine years. This association was evident after factoring in age, socioeconomic status, auditory perception skills, word decoding skills, general intelligence, and the number of hours children read per week. Moreno et al (2011) studied 72 children between the ages of four and six years participating in a summer camp. The students were divided into a visual arts group and a music group to determine whether short-term music instruction has an impact on preliteracy skills. Students receiving music instruction demonstrated greater improvement with rhyme awareness and preliteracy skills. A longitudinal study by Slater et al (2014) also demonstrated that music

instruction provided reading performance benefits for students in a low socioeconomic status (SES) neighborhood in Los Angeles.

Verbal Memory, Verbal Ability and Nonverbal Reasoning

On the basis of earlier research that demonstrated a relationship between music instruction and verbal memory performances, Roden et al (2012) studied the development of verbal and visual memory in students from the first through the fourth grades. Students were divided into a music study group, a natural science study group, and a control group who received no extra training in either discipline. The study tested the students three times over the course of 18 months, and the findings revealed that the music study group scored significantly higher in verbal memory and verbal delay recall than either the natural science or the control groups.

Several early studies have demonstrated the correlation of music instruction and motor skills. One such study by Forgeard et al (2008) examined the correlation between learning music and verbal ability by studying the development of fine motor skills, melodic discrimination, verbal ability (vocabulary), and nonverbal reasoning in students who had received at least three years of musical training. The study looked at 59 students, 18 of whom were nonmusicians and formed the control group. The children who had studied music outperformed the control group in motor skills, melodic discrimination, verbal ability (vocabulary), and nonverbal reasoning.

Cognition and Brain Development

One of the emerging subsets of the research on music instruction and language development is the connection to cognition and neuroplasticity. Several studies highlight this connection, demonstrating that music training changes the structure, function and growth of the brain (Scripp & Gilbert, 2016). Studies have also demonstrated that early music training modifies functional brain structure, especially motor control and auditory processing (Proverbio et al 2013), and that early continuous musical training impacts the growth of the cerebellum, the size of the callosum, and the density of gray matter in cells (Hutchinson et al 2003). Further, musical training builds brain capacity directly related to cognitive functions that support mental processing in other domains, specifically that music and language share neural networks (Mannes, 2011).

Rauscher and Hinton (2011) explored several areas of benefit of music instruction on cognition including spatial-temporal reasoning, auditory discrimination, and phonetic awareness through a variety of

studies with preschool and elementary students. In a study by Seppanen et al (2012), their results demonstrated that musical training enhanced rapid plasticity in the brain, which is associated with a higher working memory capacity. Research evidence indicated that music training assists the neural encoding of speech (Patel, 2014). Tiermery et al (2013) demonstrated that group high school music classes enhance neural processing of speech.

Emotional Well-Being

Beyond the academic benefits of music instruction, Costa-Giomi (2004), Hallam (2010), and Hallam and Prince (2000) examined the relationship between music instruction and self-esteem. These studies demonstrated a positive relationship between music instruction and personal and social development, specifically awareness of others and social skills (including an increase in confidence). Pitts (2007) demonstrated that experiences in rehearsal and performance facilitate the overall social life of the students. Resnicow et al (2004) demonstrated a relationship between the ability to recognize emotions in musical performances and emotional intelligence. Osborne et al (2016) found that students who learned a musical instrument scored higher when measuring emotional well-being, and Eerola and Eerola (2014) found a positive relationship between the effects of music instruction and social benefits.

Socioeconomic Status

Decades of research has demonstrated a relationship between low SES and school success, to the extent that low SES can be a predictor of lower academic performance (Sirin, 2005). A number of the studies on music instruction and academic performance considered the impact of music instruction on SES as an academic indicator. A longitudinal study by Slater et al (2014) demonstrated that music instruction provided reading performance benefits for students in a low SES neighborhood in Los Angeles, suggesting that music instruction can help combat the eroding effects of low SES on learning performance. Miksza (2007) performed a quantitative longitudinal study to examine the relationships among music participation (band, chorus, and orchestra), SES, and standardized measurements of achievement in math, reading, social studies, and science. Data from over 5000 students in grades eight, 10, and 12 were used from over a four-year period, with students being identified as either nonparticipants in music or participants in band, orchestra, or choir. SES was measured using a composite variable constructed with weighted combinations of family information provided

through a questionnaire. Academic performance was measured through testing sessions, with all reliability coefficients reported by the National Center for Educational Statistics. The results demonstrated that students who participated in music instruction had a significantly higher academic performance, even when SES was factored in. In other words, when participating in music instruction, students with SES factors that may otherwise indicate lower academic performance scored academically consistent with their peers with higher SES factors.

In another quantitative study, Catterall et al (1999) examined data from the National Educational Longitudinal Survey, which collected data from more than 25,000 students over 10 years. The research demonstrated that students who reported consistently high levels of involvement in instrumental music over the middle and high school years showed significantly higher levels of mathematics proficiency by grade 12. This observation was true in general and also for low SES students as a subgroup. For the eighth graders in the study, the percentages of students identified as low SES students who demonstrated consistently high involvement in orchestra and/or band had math scores that outscored their low SES peers not involved in music by two to one. For groups of 12th graders, 33% of high-music/low-SES students tested at high levels of mathematics proficiency. When compared with other groups, only 21% of the overall group scored at high levels in math, and just 15.5% of students classified as no music/low SES scored at high levels in math. The rate of students identified as low SES who scored high in math doubled for students who had high involvement in music. These studies demonstrate that learning music increases academic scores regardless of a student's SES. Another way to consider these data is that participation in music negates the typical impacts of low SES factors on student performance—i.e., music instruction can level the academic playing field for students from low SES environments.

Another aspect of socioeconomic status and music is the concern over accessibility to music instruction. Offering music as an elective may mean that students with parents without adequate income are less likely to elect music instruction, despite the clear benefits for achievement. Several quantitative studies looked at data from students enrolled in music electives at large, public school districts (Kinney, 2008, 2010, 2019). In these programs the students did not have to pay to receive music instruction, yet students from higher SES families were more likely to choose the program and persist than low SES students who largely did not enroll or discontinued instruction. This suggests that cost may not be the only barrier for entering elective music instruction when accounting for SES.

Making the Case for Maintaining Music Curriculum

Despite the abundance of research that demonstrates the relationship between music instruction and improved academic performance, music continues to be a cocurricular or elective experience for many school systems. As such, the cost of music instruction is often placed upon the parents to purchase or rent instruments and, in some cases, pay for instruction. The cost to own a musical instrument—or rent one—can be prohibitive for lower SES families. As some studies have examined, a parent’s ability to pay for an instrument influences the likelihood a student will enroll and persist in music instruction (Corrigall and Schellenberg 2015), which means that the financial advantages of some families translate to an academic advantage for the children of those families.

By continuing to view music as an elective subject unrelated to core academic learning, students with parents without adequate income are less likely to elect music instruction, despite the clear benefits, which are particularly potent for students in low SES households. During the very difficult financial decisions that lie ahead for school districts, transforming music instruction from an elective program to more accessible curriculum provides access to all students. Music instruction greatly contributes to negating the effects of low SES on academic performance and provides clearly documented academic and developmental benefits that directly impact student performance in state mandated subjects.

References

- Abril, C.R. and Gault, B.M (2008). The state of music in secondary schools: The principal’s perspective. *Journal of Research in Music Education*, 56(1). DOI: 10.1177/0022429408317516.
- Bahna-James, T., (1991). The relationship between mathematics and music: Secondary school student perspectives. *The Journal of Negro Education*, 60(3), 477-485. DOI: 10.2307/2295499.
- Baker, R.A. Jr., (2012). The effects of high-stakes testing policy on arts education. *Arts Education Policy Review*, 113, 17-25. DOI: 10.1080/10632913.2012.626384.

Billhartz, T.D., Bruhn, R.A., & Olson, J.E. (1999). The effect of early music training on child cognitive development. *Journal of Applied Developmental Psychology, 20*(4), 615-636. DOI: 10.1016/S0193-3973(99)00033-7.

Cabanac, A., Perlovsky, L, Bonnoit-Cabanac, M., & Cabanac, M. (2013). Music and academic performance. *Behavioural Brain Research, 256*, 257-260. DOI: 10.1016/j.bbr.2013.08.023.

Catterall, J.S., Chapleau, R., & Iwanaga, J., (1999). Involvement in the arts and human development: general involvement and intensive involvement in music and theatre arts. In E.B. Fiske (Ed.), *Champions of Change: He Impact of the Arts on Learning* (pp. 1-18). Arts Education Partnership and President Committee on the Arts and Humanities, Washington, DC.

Corrigan, K. A., & Trainor, L.J., (2011). Associations between length of music training and reading skills in children. *Music Perception, 29*(2), 147-155. DOI: 10.1525/mp.2011.29.2.147.

Corrigan, K.A., & Schellenberg, E.G., (2015). Predicting who takes music lessons: parent and child characteristics. *Frontiers in Psychology, 6*(282), 00282. DOI: 10.3389/fpsyg.2015.00282.

Costa-Giomi, E., (2004). Effects of three years of piano instruction on children's academic achievement, school performance and self-esteem. *Psychology of Music, 32*(2), 139-152.

Costa-Giomi, E., (2012). Music instruction and children's intellectual development: The educational context of music preparation. In R. MacDonald, G. Kreutz, & L. Mitchell (Eds.), *Music, Health, and Well-being*. pp. 339-366. Oxford University Press, New York.

Deere, K.B., (2010). *The Impact of Music Education*. Doctoral dissertation, Union University, Jackson, Tennessee.

Degé, F., & Schwarzer, G., (2011). The effect of a music program on phonological awareness in preschoolers. *Frontiers in Psychology, 2*, 00124. DOI: 10.3389/fpsyg.2011.00124.

dos Santos Luiz, Coimbra, D., & da Silva, C.F., (2009). Musical learning and cognitive performance. *International Symposium on Performance Science, 1-6*. DOI: 10.13140/2.1.5018.9761.

dos Santos Luiz, C., Mónico, L.S.M., Almeida, L.S., & Coimbra, D., (2016). Exploring the long term associations between adolescents' music training and academic achievement. *Musicae Scientiae*, 20(4), 512-527, DOI: 10.1177/1029864915623613

Eerola, P.S., & Eerola, T., (2014). Extended music education enhances the quality of school life. *Music Education Research*, 16(1), 88-104. DOI: 10.1080/1461808.2013.829428.

Eisner, E.W., (1998). Does experience in the arts boost academic achievement? *Art Education*, 100(1), 32-40. DOI: 10.1080/10632919809599448.

Forgeard, M., Winner, E., Norton, A., & Schlaug, G., (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning. *PLoS ONE*, 3(10): e3566. DOI: 10.1371/journal.pone.0003566.

François, C., Chobert, J., Besson, M., & Schon, D., (2013). Music training for the development of speech segmentation. *Cerebral Cortex*, 23(9), 2038-2043. DOI: 10.1093/cercor/bhs180.

Gouzouasis, P., Guhn, M., & Kishor, N., (2007). The predictive relationship between achievement and participation in music and achievement in core grade 12 academic subjects. *Music Education Research*, 9(1), 81-92. DOI: 10.1080/14613800601127569.

Graziano, A.B., Peterson, M., & Shaw, G. L. (1999). Enhanced learning of proportional math through music training and spatial-temporal training. *Neurological Research*, 21(2), 139-152. DOI: 10.1080/01616412.1999.11740910.

Hallam, S., (2010). The power of music: its impact on the intellectual, social and personal development of children and young people. *International Journal of Music Education*, 28(3), 269-289. DOI: 10.1177/0255761410370658.

Hallam, S., & Prince, V. (2000). *Research into Instrumental Music Services*. Institute of Education, University of London.

Hallam, S., and Rogers, K., (2016). The impact of instrumental music learning on attainment at age 16: a pilot study. *British Journal of Music Education*, 33(3), 247-261. DOI: 10.1017/S0265051716000371.

Helmrich, B.H., (2010). Window of opportunity? Adolescence, music and algebra. *Journal of Adolescent Research*, 25(4), 557-577. DOI: 10.1177/0743558410366594.

Holochwost, S.J., Propper, C.B., Wolf, D.P., Willoughby, M.T., Fisher, K.R., Kolacz, J., Volpe, V.V., & Jaffee, S.R., (2017). Music education, academic achievement, and executive functions. *Psychology of Aesthetics, Creativity, and the Arts*, 11(2), 147-166. DOI: 10.1037/aca0000112.

Hurwitz, I., Wolff, P.H., Bortnick, B.D. & Kokas, K. (1975). Nonmusical effects of the Kodaly music curriculum in primary grade children. *Journal of Learning Disabilities*, 8(3), 167-174. DOI: 10.1177/002221947500800310.

Hutchinson, S., Lee, L.H., Gaab, N., & Schlaug, G. Cerebellar volume of musicians. *Cerebral Cortex*, 13(9), 943-949. DOI: 10.1093/cercor/13.9.943.

Kenna, J.L., & Russell, W.B. III. (2015). How did we get here? Common core and the history of standards in social studies education. In T.N. Turner, J. Clabough, & W. Cole (Eds.), *Getting at the Core of the Common Core with Social Studies* (pp. 5–24). Information Age Publishing.

Kinney, D.W., (2008). Selected demographic variables, school music participation, and achievement test scores in urban middle school students. *Journal of Research in Music Education*, 56(2), 145-161. DOI: 10.1177/0022429408322530.

Kinney, D.W., (2010). Selected nonmusic predictors of urban students' decisions to enroll and persist in middle school band programs. *Journal of Research in Music Education*, 57(4), 334-350. DOI: 10.1177/0022429409350086.

Kinney, D.W., (2019). Selected nonmusic predictors of urban students' decisions to enroll and persist in middle and high school music ensemble electives. *Journal of Research in Music Education*, 67(1), 23-44. DOI: 10.1177/0022429418809972.

Klinedinst, R.E. (1991). Predicting performance achievement and retention of fifth-grade instrumental students. *Journal of Research in Music Education*, 39(3), 225-238. DOI: 10.2307/3344722.

Mannes, E. (2011). *The Power of Music: Pioneering Discoveries in the New Science of Song*. Walker & Co.

Miksza, P., (2007). Music participation and socioeconomic status as correlates of change: a longitudinal analysis of academic achievement. *Bulletin of the Council for Research in Music Education*, 172, 41-58.

Miller, A. & Coen, D. (1994). The case for music in the schools. *The Phi Delta Kappan*, 75(6), 459-461.

Moreno, S., Friesen, D., & Bialystok, E., (2011). Effect of music training on promoting preliteracy skills: preliminary causal evidence. *Music Perception*, 29(2), 165-172. DOI: 10.1525/MP.2011.29.2.165.

Osborne, M.S., McPherson, G.E., Faulkner, R., Davidson, J.W., & Barrett, M.S., (2016). Exploring the academic and psychosocial impact of El Sistema-inspired music programs within two low socio-economic schools. *Music Education Research*, 18(2), 156-175. DOI: 10.1080/14613808.2015.1056130.

Patel, A. D., (2014). Can nonlinguistic musical training change the way the brain processes speech? The expanded opera hypothesis. *Hearing Research*, 308, 98-108. DOI: 10.1016/j.heares.2013.08.011.

Patscheke, H., Degé, F., & Schwarzer, G., (2016). The effects of training in music and phonological skills on phonological awareness in 4- to 6-year old children of immigrant families. *Frontiers in Psychology*, 7, 01647. DOI: 10.3389/fpsyg.2016.01647.

Pitts, S.E., (2007). Anything goes: A case study of extra-curricular musical participation in an English secondary school. *Music Education Research*, 9(1), 145-165. DOI: 10.1080/14613800601127627.

Proverbio, A.M., Manfredi, M., Zani, A., & Adorni, R. (2013). Music expertise affects neural bases of letter recognition. *Neuropsychologia*, 51(3), 538-549. DOI: 10.1016/j.neuropsychologia.2012.12.001.

Putkinen, V., Tervaniemi, M., & Huotilainen, M., (2013). Informal musical activities are linked to auditory discrimination and attention in 2-3-year-old children: an event-related potential study. *European Journal of Neuroscience*, 37, 654-666. DOI: 10.1111/ejn.12049.

Rauscher, F.H., & Hinton, S.C., (2011). Music instruction and its diverse extra-musical benefits. *Music Perception*, 29(2), 215-226. DOI: 10.1525/MP.2011.29.2.215.

Rauscher, F.H., & Zupan, M.A., (2000) Classroom keyboard instruction improves kindergarten children's spatial-temporal performance: A field experiment. *Early Childhood Research Quarterly*, 15(2), 215-228. DOI: 10.1016/S0885-2006(00)00050-8.

Resnicow, J.E., Salovey, P., & Repp, B.H. (2004). Is recognition of emotion in music performance an aspect of emotional intelligence? *Music Perception*, 22(1). 145-158. DOI: 10.1525/mp.2004.22.1.145.

Rickard, N.S., Bambrick, C.J., & Gill, A., (2012). Absence of widespread psychosocial and cognitive effects of school-based music instruction in 10–13-year-old students. *International Journal of Music Education*, 30(1), 57-78. DOI: 10.1177/0255761411431399.

Robitaille, J.P., & O'Neal, S., (1981). Why instrumental music in elementary schools? *Phi Delta Kappan*, 63(3), 213.

Roden, I., Kreutz, G., & Bongard, S., (2012). Effects of a school-based instrumental music program on verbal and visual memory in primary school children: a longitudinal study. *Frontiers in Psychology*, 3, 00572. DOI: 10.3389/fpsyg.2012.00572.

Schellenberg, E.G., (2004). Music lessons enhance IQ. *Psychological Science*, 15(8), 511-514. DOI: 10.1111/j.0956-7976.2004.00711.x.

Schlaug, G., Norton, A., Overy, K., & Winner, E. (2005). Effects of music training on the child's brain and cognitive development. *Annals of the New York Academy of Sciences*. 1060, 219-230. DOI: 10.1196/annals.1360.015.

Scripp, L., & Gilbert, J., (2016). Music Plus Music Integration: a model for music education policy reform that reflects the evolution and success of arts integration practices in 21st century American public schools. *Arts Education Policy Review*, 117(4), 186-202. DOI: 10.1080/10632913.2016.1211923.

Seppänen, M., Pesonen, A.K., & Tervaniemi, M., (2012). Music training enhances the rapid plasticity of P3a/P3b event-related brain potentials for unattended and attended target sounds. *Attention, Perception, & Psychophysics*, 74, 600-612. DOI: 10.3758/s13414-011-0257-9.

Sirin, S.R. (2005). Socioeconomic status and academic achievement: A meta-analytical review of research. *Review of Educational Research*, 75(3), 417-453. DOI: 10.3102/00346543075003417.

Slater, J., Strait, D.L., Skoe, E., O'Connell, S., Thompson, E., & Kraus, N., (2014). Longitudinal effects of group music instruction on literacy skills in low-income children. *PLoS One*, 9(11), 0113383. DOI: 10.1371/journal.pone.0113383.

Tierney, A., Krizman, J., Skoe, E., Johnston, K., & Kraus, N., (2013). High school music classes enhance the neural procession of speech. *Frontiers in Psychology*, 4, 00855. DOI: 10.3389/fpsyg.2013.00855.

Vidal, M., Lousada, M., & Vigário, M., (2020). Music effects on phonological awareness development in 3-year-old children. *Applied Psycholinguistics*, 41(2), 299-318. DOI: 10.1017/S0142716419000535.

Wetter, O.E., Koerner, F., & Schwaninger, A., (2009). Does musical training improve school performance? *Instructional Science*, 37, 365-374. DOI: 10.1007/s11251-008-9052-y.

Young, L.N., Cordes, S., & Winner, E., (2013). Arts involvement predicts academic achievement only when the child has a musical instrument. *Educational Psychology*, 34(7), 849-861. DOI: 10.1080/01443410.2013.785477.

Music Paintings and the Fashioning of an Early Modern Cardinal in Rome: The Case of Cardinal Francesco Maria del Monte

Charlotte Tanner Poulton
Utah Valley University

Abstract

The display of paintings in seventeenth-century Roman palaces was integral to the social virtue of splendor intended to convey the owner's social, political, and, in the case of cardinals, ecclesiastical importance. Recent research has shed additional light on the careful consideration given to the rooms in which paintings were to be hung and viewed based on the rank and status of guests who were admitted into those spaces. This necessitates a reevaluation of the presence of music paintings, which, too often, have been dismissed as a minor genre of merely descriptive representations of contemporary music practices. This paper investigates the implications of the display of music paintings by Caravaggio and Antiveduto Grammatica in the palace of Cardinal Francesco Maria del Monte. Parallel examinations of music paintings in the palaces of Vincenzo Giustiniani and cardinals Francesco and Antonio Barberini reveal similar patterns of display. This paper contends that while paintings of musical subjects are relatively few, surprisingly, they were hung in prominent locations in the private

residences of Rome's most powerful and influential cardinals. These paintings were instrumental in helping Cardinal del Monte achieve splendor and fashion himself as a leading arbiter of taste in both painting and music in Rome.

The display of paintings in seventeenth-century Roman palaces was part of a larger program of magnificence and splendor intended to convey the owner's social, political, and, in the case of cardinals, ecclesiastical importance. Recent research has shed additional light on the careful consideration given to the particular rooms in which art was displayed and viewed based on the rank and status of visitors who were admitted into those spaces.¹ In this case, the presence of music paintings in the collections of Rome's intellectual and cultural elite deserves careful examination. These images have been dismissed too often as a minor genre of merely descriptive representations of contemporary music practices. A fresh focus here on the display of music paintings specifically in the palace of Cardinal Francesco Maria del Monte will provide an instructive point of departure. Cardinal del Monte was elected to the cardinalate in 1588 and served as agent for the interests of Ferdinand II, the Grand Duke of Tuscany. He was a refined man but early in his career he lacked the personal wealth and political power of many of his fellow cardinals who claimed higher ecclesiastical and secular nobility.² However, del Monte soon became a powerful patron at the forefront of progressive developments in both painting and music in early seventeenth-century Rome. This paper will argue that the display of music paintings in his Palazzo Madama was not merely illustrative of the cardinal's patronage, as most scholarship asserts, but rather was strategically planned and instrumental in helping the cardinal build his reputation and fashion himself as one of the leading arbiters of musical and artistic taste in Rome.

An avenue of investigation that has been overlooked until now is the parallel between the architectural accommodation of musical performances and music paintings. Cardinal del Monte created a room

¹ On architectural plans and the carefully orchestrated etiquette associated with hosting ecclesiastical and diplomatic visitors in Roman courts, see Patricia Waddy, "Many Courts, Many Spaces," in *The Politics of Space: European Courts ca. 1500-1750*, ed. Marcello Fantoni, George Gorse, and Malcolm Smuts (Rome: Bulzoni Editore, 2009), 209-230.

² In the early 1580s, Cardinal del Monte served in the court of Cardinal Ferdinando de' Medici, who renounced his position to become Grand Duke of Tuscany. It was likely through this connection with the powerful Medici cardinal/duke that del Monte was included in the circles of ecclesiastical elites such as Cardinal Alessandro Peretti di Montalto, Cardinal Scipione Borghese, Cardinal Pietro Aldobrandini, and Cardinal Maffeo Barberini.

in the Palazzo Madama to house musical instruments and musical performances, as described in a letter he wrote to Ferdinand II, the Grand Duke of Tuscany, on November 22, 1589: "Today [Cardinal] Montalto was here for a time in this house, where I have set aside a room for harpsichords, guitars, a chitarrone and other instruments, and he has taken such a liking to it, that he says that he will be good enough to favour me with frequent visits, and come and dine with me."³ Since the Palazzo Madama belonged to Ferdinand, perhaps del Monte was reassuring the Grand Duke that by reserving a room for primarily, if not exclusively, music purposes, his ecclesiastical residence closely imitated the magnificence established in Italian courts of secular princes.⁴ Such rooms were an integral part of a network of rooms devoted to leisure pursuits—ball courts, libraries, game rooms, and art galleries—that provided the cardinal with diversions from the serious audiences and responsibilities associated with his official capacity.⁵ They contributed to the patron's dynastic display as one wealthy and cultured enough to acquire musical instruments, maintain a household of musicians, and promote the most fashionable musical styles.

For Cardinal del Monte, a skilled amateur guitarist, the promotion of leading singers and instrumentalists in his palace not only accommodated his passion for music but also served as an extension and promotion of various official capacities.⁶ He was appointed in 1594 by Pope Clement VIII to oversee reforms in liturgical music in keeping with

³ Zygmunt Wazbinski, *Il Cardinale Francesco Maria del Monte 1549-1626*, vol. 1 (Florence: Leo S. Olschki Editore, 1994), 137-38. Translated in Helen Langdon, *Caravaggio: A Life* (New York: Farrar, Straus and Giroux, 1999), 107.

⁴ Fabio Albergati's *Il Cardinale* (Rome, 1664), 244. Brigham Young University Special Collections. *Il Cardinale*, a treatise dedicated to Cardinal Odoardo Farnese, strongly advocates that the Cardinal Prince should rival, if not surpass, secular princes in the splendor of his residence and possessions. "The cardinal prince, therefore, if he wanted to consider that which was often done by many princes, would be pleased to have a house full of servants corresponding to his greatness, and of such signal nobility, that every kind of office would be assured by illustrious and titled person; since as the commander of the more worthy subjects he renders the greatness of superiority much more esteemed and admirable. He would spend his income in those actions for the sake of his decorum, for the ornament of the house in the lodging, manufacturing, and banqueting, he would seek a supreme magnificence, just as the cardinal born prince must be disposed to do in relation to his servants and to his house."

⁵ Patricia Waddy, *Seventeenth-Century Roman Palaces: Use and the Art of the Plan* (New York: The Architectural History Foundation and Cambridge: The MIT Press, 1990), 54-60. The Grand Duke's own Pitti Palace in Florence was designed to accommodate a variety of lavish entertainments. Leon Satkowski, "The Palazzo Pitti: Planning and Use in the Grand-Ducal Era," *The Journal of Architectural Historians* 42 (December 1983), 341.

⁶ On the musicians sponsored by Cardinal del Monte, see Franca Trincieri Camiz, "Music and Painting in Cardinal del Monte's Household," *Metropolitan Museum Journal* 26 (1991), 213-226.

decrees of the Council of Trent.⁷ In addition to this key position overseeing sacred music practices in Rome, he was appointed in 1596 as one of the two reformers of the recently founded painting Academy of St. Luke.⁸ These appointments coincided closely with del Monte enrolling into his household the young artist Caravaggio, whose revolutionary style took Rome by storm. Music and painting, therefore, were crucial components of Cardinal del Monte's private and public persona.

Significant interrelationships of aural and visual splendor play out in music rooms like the one in del Monte's palace, and musician paintings contributed to an overall sensory experience within these settings. In his treatise on the role of cardinals, (*De Cardinalatu* (San Gimignano, 1510), Paolo Cortesi delineates the specifications of a cardinal's residence required for functional and aesthetic reasons to complement the cardinal's aim to lead, in Cortesi's view, "an orderly, virtuous life."⁹ The presence of music within the cardinal's household to aid in this goal is revealed by a brief reference that presumes a separate music room as a standard feature of palace architecture, one specially designed to enhance the acoustics of both singing and playing of music¹⁰

Music rooms were unique in their design because they were the only rooms in a palace where an appeal to the sense of hearing was paramount. However, aural delight was only half the formula for generating a profound sensory experience; the other half was an appeal to the sense of sight through the decoration of the room. This conjunction of music and painting in designated physical spaces within a palace corresponds with the way these arts are linked in the treatise to new cardinals written by the wealthy banker, art patron, and close friend of Cardinal del Monte, Marchese Vincenzo Giustiniani. Like Cortesi,

⁷ The Congregation of Sacred Rites were responsible for overseeing all matters related to the liturgy. When objections arose about printing Palestrina's reformed Gradual, Cardinal del Monte was tasked with overseeing a careful inspection of the manuscript by four expert composers. Joshua Joel Veltman, "Prosody and Rhythm in the Post-Tridentine Reform of Plainchant," Ph.D. dissertation. (Columbus: The Ohio State University, 2004), 65.

⁸ Alessandra Buccheri, *The Spectacle of Clouds, 1439-1650: Italian Art and Theater*, (London: Ashgate, 2014), 124.

⁹ Katherine Weil-Garris and John F. D'Amico, "The Renaissance Cardinal's Ideal Palace: A Chapter from Cortesi's *De Cardinalatu*," *Memoirs of the American Academy in Rome 35: Studies in Italian Art History I: Studies in Italian Art and Architecture 15th through 18th centuries*, ed. Henry Al Millon (Rome, 1980), 73.

¹⁰ "Yet there is no reason why the summer apartments and the music rooms should not be placed in the northern part of the palace... The music rooms have been given a round vaulted ceiling lest the voice wander or be lost. And hence we read that bronze vases or earthenware jars are often put into niches in the walls of the music rooms. This is done for the sake of the music, so that sound coming from the middle of the room strikes against the empty vessels, making both singing and playing sound much sweeter." *Ibid*, 78-79.

Giustiniani recognized the capacity of a cardinal's palace for helping to establish his social and ecclesiastical authority.¹¹ Most intriguing about the structure and content of Giustiniani's treatise is the importance given to the arts of painting and music as separate sections for discussion in between instructions about palace construction, traveling, hunting, and household protocol. The discourse on painting outlines 12 modes of painting related to naturalism and the use of light, dark, color, design, and perspective, and it praises artists like Raphael, Guido Reni, and Caravaggio who successfully apply these techniques to historical subjects, landscapes, and flower pieces.¹² The discourse on music makes reference to innovative music of composers like Luca Marenzio and Carlo Gesualdo and champions individual singers and instrumentalists who perform the music in Italian courts.¹³ By positioning together sections defining the most fashionable practices of painting and music in relation to sections detailing architectural specifications and social requirements of receiving and entertaining certain guests, Giustiniani suggests that a cardinal's education in the production and patronage of these arts was essential to successfully maintaining his office. He also implies indirectly that the arts were and should be engaged in a complementary relationship within the physical structure of a cardinal's household.

Although no mention of the music room's decoration appears in del Monte's letter to Grand Duke Ferdinand, the inventory of paintings in the "third room on the right" lists exclusively female portraits and paintings of musical subjects. Helen Langdon submits that this is the music room set aside by del Monte and that Caravaggio's *The Musicians* (c. 1595) (Fig. 1) and *Lute Player* (c. 1597) (Fig. 2) hung on the walls here alongside four other paintings of musicians.¹⁴ At least two of these,

¹¹ The individual sections are titled as follows: 1. Dialogo tra Renzo (romano) e Aniello napoletano sopra gli usi di Roma e di Napoli, 2. Avvertimenti per uno scalco 3. Istruzione necessaria per fabbricare, 4. Istruzione per far viaggi, 5. Discorso sopra la pittura, 6. Discorso sopra la musica, 7. Discorso sopra la caccia, 8. Istruzione per un maestro di camera. Archivio di Stato, Lucca, Fondo G.B. Orsucci 48 (olim O. 49). This manuscript copy is dated 1640 and was owned by Nicolo Orsucci.

¹² *Ibid.* fos. 105-111.

¹³ *Ibid.*, fos. 113-135.

¹⁴ Langdon, 113. Other music paintings were a picture of Orpheus by Bassano and a scene of Parnassus by Grammatica. *The Concert* by Grammatica has been lost, but the composition is known through photographs of a copy, as reproduced in Keith Christiansen, *A Caravaggio Rediscovered*, 27. Honthorst's painting was bought by Francesco Barberini and appears in the 1626-31 inventory as "Una donna che sona la citarra, con due alter figure, o' tre di huomini, che cantano, e sonano a'lume di candela, opera di Girardo fiam'e'go." Lavin 89.



Fig. 1. Caravaggio, *The Musicians*, c. 1595, The Metropolitan Museum of Art, New York.



Fig. 2. Caravaggio, *The Lute Player*, c. 1597, The Metropolitan Museum of Art, New York.

a concert scene by Gerrit van Honthorst and *Concert* by Antiveduto Grammatica (c. 1615) (Fig. 3), were later acquired by Antonio Barberini.¹⁵ If Langdon is correct, then these paintings were viewed by members of del Monte's most intimate and prominent intellectual and cultural circles within the context of a musical environment. Therefore, the implications of setting and space, both compositionally within the confines of the painting and architecturally within the palace walls, must be taken into account. As Gail Feigenbaum points out, "paintings... were designed to operate in the physical and social conditions of [their] setting, much in the way an altarpiece was designed to work in a chapel."¹⁶ What is striking about Caravaggio's *Lute Player* and Antiveduto Grammatica's *Concert* is the elimination of any extraneous references to a particular setting.



Fig. 3 Copy after Antiveduto Grammatica, *Concert*.

¹⁵ The 1626-31 and 1649 inventories of Francesco Barberini's possessions describe an image of a woman playing a Spanish guitar painted by Honthorst. The copy of Grammatica's painting was attributed to Cantarini and sold at the Michelsen sale, Bangel, Frankfurt in 1922 as catalog number 1030. The surviving photograph was published in Hermann Voss, "Caravaggio's Freiheit," *lahrbuch der Preussischen Kunstsammlungen* 44 (1923): 79; and subsequently in Richard Spear, *Caravaggio and His Followers* (Cleveland: Cleveland Museum of Art, 1971), 106. The photograph reproduced here was taken from Christiansen, *A Lute Player Rediscovered*, 27.

¹⁶ Gail Feigenbaum, "Introduction: Art and Display in Principle and in Practice," in *Display of Art in the Roman Palace 1550-1750*, ed. Gail Feigenbaum (Los Angeles: J. Paul Getty Trust, 2014), 20.

The dark background against which the musicians are placed and the tables with music books and musical instruments in the foregrounds hint at a possible interior setting but nothing more. If these works were hung in a music room where musical instruments were housed and displayed and where musicians practiced and performed, could it be that the undefined setting within the painting would have been visually completed by the architecture and ornamentation of the music room? With no reference to a predetermined architectural setting, these paintings are joined spatially, thematically, and symbolically to the environment they inhabit. Any potential for the eye to explore beyond the musicians is halted abruptly by the dark wall, which causes the space within the image to project outward toward the viewer. In this sense, the musical performances depicted in the paintings become substitutes for actual performances heard in the music room. The instruments and music books that extend off the edge of the table into the viewer's space create a sense of immediacy and invite closer interaction between the painted concert and the audience.

Cardinal del Monte's audience would have recognized that Caravaggio and Grammatica present portraits of well-known contemporary musicians. Franca Camiz proposes that the figure in *Lute Player* is Pedro Montoya, a Spanish castrato singer in the Sistine Chapel choir employed in del Monte's household at the same time as Caravaggio and, therefore, advertises the Cardinal's ability to sponsor highly skilled singers.¹⁷ In Grammatica's work, the theorbo player has been identified as Cesare Marotta and the harpsichordist as his wife, the famed singer Ippolita Recupito.¹⁸ These two were among the most "highly paid and widely praised" musicians in the circles around Rome's ecclesiastical elite and were members of the household of Cardinal del Monte's friend, Cardinal Alessandro Peretti di Montalto.¹⁹ During the decades at the turn of the century, Cardinal del Monte and his colleagues took turns hosting one another at extravagant banquets and musical entertainments for members of their most intimate intellectual and musical circles.²⁰ Cardinal del Monte likely would have enjoyed performances by Marotta and his wife, and with Grammatica's painting of them in concert, he seems to offer his seal of approval to their music and, perhaps, claim for himself a place for these musicians in his household.

¹⁷ Franca Trincieri Camiz, "'La Musica' nei dipinti di Caravaggio," *Quaderni di Palazzo Venezia 6, Caravaggio, nuove riflessioni* (1989): 207-209.

¹⁸ P.G. Tortella, "Antiveduto Grammatica, Ottavio Leone e le musiciens du Cardinal Montalto," *Le revue des musees de France: revue du Louvre*, 1 (2015), 24-31.

¹⁹ John Walter Hill, *Roman Monody, Cantata, and Opera from the Circles Around Cardinal Montalto* (Oxford: Clarendon Press: 1997), 203.

²⁰ Helen Langdon, *Caravaggio: A Life*, 107.

In addition to celebrating leading musicians, the left side of Grammatica's painting (Fig. 4) encourages the viewer to consider how the concert explores in a single image the values of different current musical styles. The inclusion of a theorbo, guitar, and tambourine is remarkable because they allude to the practice of monody individually and collectively. Solo singing accompanied by a guitar or theorbo was a particularly attractive option for professional musicians.²¹ These two instruments in concert with a tambourine point to the forward-looking compositions of Emilio de' Cavalieri, with which Cardinal del Monte



Fig. 4. Antiveduto Grammatica, *Theorbo Player* (right half of original composition), c. 1608-10, Galleria Sabauda, Turin.

²¹ Guitars were rarely used on their own in theatrical settings because they were not capable of producing the necessary volume, and their music was often reinforced by other lutes or guitars backstage. In intimate chamber settings, however, a relatively small room's acoustical properties accommodated a single continuo instrument like a guitar or lute. Nina Treadwell "The 'Chitarra Spagnola' and Italian Monody, 1589 to circa 1650. Master's thesis. Los Angeles: University of Southern California, 1995, 18, 78. For a brief summary of how the guitar accommodated early monody, see James Tyler, "The Role of the Guitar in the Rise of Monody: The Earliest Manuscripts," *Journal of Seventeenth-Century Music*, 9 no. 1 (2003), 1.5. <http://sscm-jscm.press.uiuc.edu/jscm/>.

had firsthand knowledge. He attended the premiere of Cavalieri's major performances in Florence and Rome.²² He was present when three guitars were used, on order of Cavalieri, to perform his *intermedi* at the wedding celebrations of Grand Duke Ferdinand de' Medici. Del Monte was present at Cavalieri's performance of "The Representation of the Soul and the Body" (*Rappresentazione di Anima, et di Corpo*, 1600) in which theorbo, guitar, and tambourine were recommended specifically for the recitational music of one part of this *opus magnum* of monody.²³ The details and positioning of individual instruments in *Concert* demonstrate how Grammatica explored and advocated pictorially what musicians were doing musically—experimenting with the compositional potential of various accompanying instruments for solo singing compositions. Cardinal del Monte leaves no room for doubt among his viewers that he is an early and enthusiastic advocate for these progressive music developments.

Although evidence to support Langdon's suppositions about the display of musician paintings in Cardinal del Monte's palace is circumstantial, inventories of objects in the Barberini palaces do reveal one direct link between paintings of musical subjects and the spaces wherein musical activities were enjoyed. Cardinal del Monte likely had access to the Palazzo Barberini because of his friendship with members of the Barberini family and their associations in various academies.²⁴ The April 1644 inventory of Cardinal Antonio Barberini's possessions records each object according to its location in the Palazzo Barberini. One of these rooms located on the ground floor of the north wing and designated as the "Room of Parnassus" is likely the same one Patricia Waddy identifies as the room whose ceiling was painted with a scene of Apollo on Mount Parnassus, making it suitable for musical performances.²⁵ Of particular interest is one of the nine entries listed for

²² Production of *Giucoco della Cieca* at the Pitti Palace in October 1595; the premier of *Dafne* by Jacopo Peri at the Casa Crosi in 1599; and Cavalieri's *Rappresentazione* in Chiesa Nuova in 1600.

²³ Murray C. Bradshaw, "Cavalieri and Early Monody," *The Journal of Musicology* 9 (Spring, 1991): 251.

²⁴ Cardinal del Monte and the Barberini family associated in the same ecclesiastical and intellectual circles. Cardinal del Monte was installed as Cardinal Protector of the Accademia di San Luca in 1595 and worked with Pope Urban VIII (Maffeo Barberini) until 1624 when the pope installed his nephew Cardinal Francesco Barberini as protector to help further his agenda.

²⁵ Antonio Barberini dramatically expanded the concept of a room designed for musical performances when, in 1637, he ordered the construction of a theater next to the palace. The Barberini family continued to sponsor performances in the large salone (C2) until the new theater was completed in 1639. Marilyn Lavin, *Seventeenth-century Barberini Documents and Inventories of Art* (New York: New York University Press, 1975), 245-47.

this room: “a picture with a young man in a chemise who plays the lute, with other musical instruments, by the hand of Caravaggio, with a gilded frame (“un quadro con un giovane in camiscia, che suona il leuto, con altri istrumenti musicali, di mano del Caravaggio, con cornice tutta dorata”).²⁶ The Caravaggio painting that hung in this room was correctly identified in 1985 by Karin Wolfe as Cardinal del Monte’s *Lute Player*. An entry in one of Antonio Barberini’s ledgers records that this painting was sold along with other paintings from Cardinal del Monte’s collection to Cardinal Antonio on May 7, 1628, by the heirs of del Monte’s estate.²⁷ Its presence in a presumed music room in the Palazzo Barberini supports Langdon’s claim about how it was displayed originally in the Palazzo Madama. If, as Langdon proposes, *Lute Player* hung in del Monte’s music room, perhaps Antonio Barberini was aware of its original setting and chose to display it in the same context in his palace. It was likely not coincidence that two cardinal’s households, both sites for the carefully orchestrated reception of learned ecclesiastical and political dignitaries, displayed the same musician painting in rooms specially designed for musical activities.

The display of Giovanni Lanfranco’s *Venus Playing the Harp* (1630-34) (Fig. 5) in the Palazzo Barberini provides intriguing evidence for the claim that Cardinal del Monte strategically displayed his music paintings for propagandistic purposes. Until now, the location of the painting in relation to other paintings hung in the room has not been investigated. It may have been displayed prominently to evoke the sounds of the harp’s music but, more importantly, may have been intended to celebrate the musical erudition of the family responsible for such music. The painting was commissioned by Marco Marazzoli, a renowned composer and harpist in the Barberini employ, and was willed to Cardinal Antonio Barberini upon Marazzoli’s death in 1662.²⁸ It depicts a half-draped Venus playing the famous carved and gilded Barberini harp, supposedly designed by Gian Lorenzo Bernini, on which Marazzoli himself played.²⁹ The 1671 inventory of Cardinal Antonio

²⁶ Lavin, 167-68.

²⁷ Karin Wolfe, “Caravaggio: Another *Lute Player*,” *Burlington Magazine* 127 (July 1985), 451-52.

²⁸ Franca Trinchieri Camiz, “The Castrato Singer: From Informal to Formal Portraiture,” *Artibus et Historiae* 9 no. 18 (1988), 183.

²⁹ The identification of Bernini as the designer of the harp was part of an oral tradition passed down through the Barberini family. For a close study of the Barberini harp, see Eleonora Simi Bonini, “Uno Strumento e la sua storia: L’arpa Barberini,” *Nuova Rivista Musicale Italiana*, (April-June, 2012): 205-225.

Barberini's paintings in the Casa Grande records Lanfranco's *Venus* as hanging in the room labeled "Stanza seg.ta L."³⁰ Unfortunately, the exact



Fig. 5. Giovanni Lanfranco. *Venus Playing a Harp*, 1630-34. Galleria Nazionale d'Arte Antica, Rome.

location and/or function of this room cannot be known with certainty, but it can be surmised that within this room Lanfranco's painting must have had a dramatic presence. The inventory entry describes it as "a picture of greatness" with a carved threaded gold frame.³¹ Not only was it the largest painting in the room, measuring 135 × 225 cm, but its value of 500 scudi far exceeded the values of the other 16 paintings in the room, which ranged from 30 to 150 scudi, with the exception of two paintings by Bassano valued at 200 scudi each.³²

³⁰ Lavin, 303. Each room was assigned a letter of the alphabet, and its paintings were inventoried separately.

³¹ Lavin, 303.

³² Also displayed in the room were paintings by Poussin, Annibale Carracci, Guercino, Barrocci, Pietro da Cortona, Agostino Tassi, and Guido Reni.

If the order in which the paintings are listed in the inventory is an indication of where paintings were hung in the room, then Lanfranco's work may have appeared next to a female allegorical figure of Geometry by Guercino. By itself, Lanfranco's image, which represents an actual, recognizable instrument, advertised to the viewer the Barberini family's involvement with music in two ways. First, they acquired splendid instruments for the finest musicians and composers in their household. Second, they sponsored performances of leading musicians and their music, which ranged from large-scale operas to more intimate vocal and instrumental chamber music.³³ Juxtaposed with Guercino's painting, however, Lanfranco's work could have evoked broader associations with music as a liberal art and promoted the Barberini family's enthusiastic support of developments in music theory, especially the influential work of the music theorist Giovanni Battista Doni (1595-1647). The Barberini family had facilitated Doni's work by allowing him to deliver discourses on music in Cardinal Francesco Barberini's academies, sponsoring innovative musical productions under his supervision, and introducing him to musicians who carried out Doni's prescriptions for musical performances.³⁴ The message to the many cardinals, ambassadors, and other noble visitors to the Casa Grande who viewed Lanfranco's painting was that patronage of both music and painting was more than a casual, pleasurable leisure activity for the Barberini family: it was serious business.

A more immediate comparative source for analyzing Cardinal del Monte's display of music paintings is the palace of his close friend and neighbor Vincenzo Giustiniani.³⁵ Like del Monte, Vincenzo Giustiniani fashioned his palace as a locus for progressive art and music at a time of controversy about what defined the best and most fashionable vocal music styles and performance practices. Leading music aestheticians fervently championed innovation over tradition, solo singing over unaccompanied polyphonic madrigals, and clarity of words and expression over technical intricacies of counterpoint. Vincenzo Giustiniani had firsthand experience with these shifting trends in music, and his opinions are expressed through Caravaggio's *Lute Player* (Fig.

³³ Among these musicians was Girolamo Frescobaldi, for whom cardinal Francesco Barberini provided music paper. Frederick Hammond, "Girolamo Frescobaldi: New Biographical Information," in *Frescobaldi Studies* (1987), 23.

³⁴ Doni dedicated his *Lyra Barberina* (1632) to Maffeo Barberini (later Pope Urban VIII), his *Compendio del trattato de' generi* (1635) to Cardinal Francesco, and his *Annotazioni sopra il Compendio* (1640) to Cardinal Antonio. Doni even constructed a unique stringed instrument that he named the *lyra Barberina* in honor of his patron. Hammond, *Music and Spectacle*, 99-100.

³⁵ Camiz, "Music and Painting", 215.

6). Giustiniani sponsored musical events at his palace, was a guest at musical activities in other Italian courts and, even included a discourse on music in his instructional treatise dedicated to Roman cardinals.³⁶ In



Fig. 6. Caravaggio, *The Lute Player*, c. 1595, Hermitage Museum, St. Petersburg

this discourse, Giustiniani expresses admiration, and almost nostalgia, for past styles of madrigal singing, but at the same time enthusiastically endorses the more recent explosion of homophonic compositions. Giustiniani's writings are key to understanding Caravaggio's *Lute Player* as more than merely a representation of musical entertainments enjoyed in households of Rome's elite, which has been the prevailing interpretation of such images. The writings support a more insightful claim that this image reconciles conflicting attitudes to monody and madrigal held by Giustiniani and his contemporaries. The musical and textual complexities of madrigals are recalled in the open partbooks of Jacques Arcadelt's earlier unaccompanied madrigals (ones that were never accompanied in later editions). Giustiniani was an impressionable

³⁶ Vincenzo Giustiniani, *Discorso sopra la musica*, Archivio di Stato, Lucca, Fondo G.B. Orsucci 48 (formerly O.49), 118-19. Other chapters in this discourse include *Dialogo tra Renzo et Aniello Napolitano sopra l'uso e costumanze di Roma e Napoli* (fos. 5-34), *Avvertimenti per uno scalco* (fos. 35-48), *Istruzione necessaria per fabbricare* (fos. 51-69), *Istruzione er far viaggi* (fos. 72-104), *Discorso sopra la pittura* (fos. 105-11), *Discorso sopra la musica* (fos. 113-35), *Discorso sopra la caccia* (fos. 137-71), and *Istruzione per un maestro di camera* (fos. 173-200).

youth when he was first introduced to Arcadelt's highly esteemed madrigals, which remained popular as a vocal music "primer" long after Arcadelt's death in 1568.³⁷ In contrast to this reference to polyphonic madrigals in *Lute Player*, the emotional engagement associated with the emerging style of monody, or accompanied solo singing, is endorsed by Caravaggio's depiction of the young musician alone, singing intently to his own lute accompaniment.³⁸ *Lute Player*, therefore, can be read as promoting Giustiniani's gesture toward a conciliatory attitude that embraces the compatibility of rather than apparent contradictions between madrigals and monody.

Caravaggio's painting was displayed prominently in the Palazzo Giustiniani, and undoubtedly was chosen for the skill of the artist and the art of painting as much as for any comment on Giustiniani's musical erudition. *Lute Player* was hung conspicuously above the door of the first "Stanza grande de quadri antichi" as recorded in the February 1638 inventory of Giustiniani's painting collection.³⁹ According to the inventory, whose entries seem to follow the palace floor plan, the "stanza grande de quadri antichi" was located on the *piano nobile* of Palazzo Giustiniani next to a series of small apartments and adjacent to a second "stanza de quadri antichi."⁴⁰ Both the inventory and Tessin's account suggest that Caravaggio's works hung in a large room prominently located near stairway access to the *piano nobile* and, therefore, were

³⁷ For example, notations and instructions in Pietro Giacomo Petrucci's 1603 publication of Arcadelt's first book indicate that the print was intended specifically for beginning students. Thomas Whitney Bridges, "The Publishing of Arcadelt's First Book of Madrigals" vols. 1-2 (Ph.D. dissertation, Cambridge, MA: Harvard University, 1982), 239-40. Giustiniani's praise for Arcadelt's madrigals in his 1628 treatise was perhaps a result of his nostalgia for that earlier period in his life and was largely shaped by early firsthand personal experience. It also may have been a result of the long-lasting popularity of Arcadelt's compositions, of which 58 editions were published between 1538 and 1654.

³⁸ He juxtaposes his musicians with carefully depicted and prominently placed renderings of well-known madrigals by Jacques Arcadelt (b. Namur 1507?; d. 1568).

³⁹ *Inventario de Quadri e Statue, 20 A. Parte IV, no. 8*, Rome, Archivio di Stato, Casa Giustiniani, Busta 16. "un quadro sopraporto con una mezza figura di un giovane che suona il Leuto con diversi frutti, e fiori e libri di musica dipinto in tela alto pal. 4. larg. pal. 5-con sua cornice negra profilata et rebescata d'oro di mano di Michelangelo da Caravaggio."

⁴⁰ Although it is difficult to ascertain the exact location of the "stanza grande," we can determine an approximate location based on room descriptions in the 1638 inventory and the account of Swedish architect Nicodemus Tessin's visit in 1673. The difficulty of determining the location of specific rooms is compounded by the fact that the Palazzo Giustiniani underwent significant renovations and remodeling between 1650 and 1673. Patricia Waddy, "Tessin's Rome," *Konsthistorisk Tidskrift* 72 no. 1 & 2 (June 2003): 115. Tessin's travels to Rome are described in Nicodemus Tessin the Younger, *Travel Notes 1673-77 and 1687-88* (Sources Works Collection), ed. Merit Laine and Börje Magnusson (Stockholm: Nationalmuseum, 2002), 310.

readily accessible.⁴¹ This room housed the pride of Giustiniani's collection—nearly 100 paintings of predominantly religious subject matter by artists including Raphael, Andrea del Sarto, Titian, Giorgione, Tintoretto, Veronese, Annibale Carracci, Lodovico Carracci, and Guido Reni. In addition to showcasing works by these recognized masters, Giustiniani used this room to demonstrate his enthusiastic support for Caravaggio and his progressive style by displaying 13 paintings by Caravaggio.⁴² *Lute Player*, with its subtle commentary on current music debates, would have been noticed by all who passed through the doorway. Displayed in company with, and in sharp contrast to, sacred images, it also would have functioned as the catalyst for comparison and discussion, an increasingly important condition for display among collectors.⁴³ It was here where Cardinal del Monte would have seen Caravaggio's *Lute Player* and been impressed—or jealous—enough to commission a version for himself. Although the composition of his version differs slightly, it still incorporates the juxtaposition of traditionally unaccompanied madrigal scores with the progressive practice of monody.

What emerges from this discussion is that the relatively minor genre of musician paintings may have played an important role within the larger social/political context of splendor and display within Cardinal

⁴¹ The inventory begins with the “sala grande,” which may be the first room entered from the stairway at the left on the plan and ends with the “stanza grande in faccia alla scala,” which may be one of the rooms near the stairway at the right. Because the inventory mentions the “stanza grande” four rooms prior to a final entry for the room facing the stairway, it could be one of the rooms located in the lower part of the plan. Waddy's reconstruction of the path taken by Nicodemus Tessin through the Palazzo Giustiniani in 1673 indicates that works by Caravaggio that Tessin saw were in rooms two and six. Waddy reconstructs Tessin's path through the palace to indicate the order in which he visited the rooms and claims that he began in the *sala* (Im ersten sahl oben), which likely is the “sala grande” mentioned in Giustiniani's inventory. Patricia Waddy, “Tessin's Rome,” 116-17. Tessin's mention of Caravaggio is brief: “Im anderen zimber [room two] wahren 8 schöne grosse stück vom Guercino undt Caravaggio,” (In another room were 8 beautiful large paintings by Guercino and Caravaggio); “im sexten wahr ein schönes stück vom M.A. Caravaggio wie Christus den jüngern di füßen wascht” (in the sixth [room] was a beautiful painting by M.A. Caravaggio of Christ washing the disciples' feet). Tessin, 310. The painting of Christ washing the disciples' feet is incorrectly attributed here to Caravaggio. This painting is correctly attributed to Dirck van Baburen in both Giustiniani's 1638 inventory and in the Gemäldegalerie, Berlin.

⁴² The subjects of the other paintings listed as being painted by Caravaggio are St. Matthew and the angel, Christ in the Garden of Gethsemane, crowning of thorns, St. Augustine, St. Jerome, portrait of the painter Gismondo Todesco, two portraits of courtesans, Mary Magdalene, doubting Thomas, and a portrait of Cardinal Benedetto Giustiniani. Ibid.

⁴³ Feigenbaum, 20. “Specialized genres, such as landscape or still life, were especially well suited for arrangements intended to provoke comparison, the favorite device on which discussion tended to pivot in the period.”

del Monte's household. These new arguments about where music paintings by Caravaggio, Lanfranco, and Grammatica were hung and how they were to be viewed are essential to expanding the discourse on music paintings and situating this genre within current dialogues about the politics of display in Roman palaces. Although few in number within Cardinal del Monte's impressive collection, and those of his contemporaries, paintings of musicians seem to have been strategically displayed to maximize their exposure to Rome's wealthy and cultured elite. Consequently, the description and prescription of contemporary music practices, as represented by some of the most progressive artists of the day, helped to reaffirm Cardinal del Monte's connoisseurship and leave little doubt that he was the cardinal most ably qualified to oversee—and even promote—developments in both music and painting in seventeenth-century Rome.

BIBLIOGRAPHY

Albergati, Fabio. *Il Cardinale*. Rome, 1664.

Bonini, Eleonora Simi. "Uno Strumento e la sua storia: L'arpa Barberini." *Nuova Rivista Musicale Italiana*, XLVI (April-June 2012): 205-225.

Bradshaw, Murray C. "Cavalieri and Early Monody," *The Journal of Musicology*, 9 (Spring, 1991): 238-253.

Bridges, Thomas Whitney. "The Publishing of Arcadelt's First Book of Madrigals," vols. 1-2, Ph.D. dissertation. Cambridge MA: Harvard University, 1982.

Buccheri, Alessandra. *The Spectacle of Clouds, 1439-1650: Italian Art and Theater*. London: Ashgate, 2014.

Camiz, Franca Trinchieri. "The Castrato Singer: From Informal to Formal Portraiture." *Artibus et Historiae*, 9 no. 18 (1988): 171-186.

Camiz, Franca Trincieri. "'La Musica' nei dipinti di Caravaggio." *Quaderni di Palazzo Venezia* 6, *Caravaggio, nuove riflessioni* (1989): 198-221.

Camiz, Franca Trincieri. "Music and Painting in Cardinal del Monte's Household." *Metropolitan Museum Journal*, 26 (1991): 213-226.

Christiansen, Keith. *A Caravaggio Rediscovered: The Lute Player*. New York: Metropolitan Museum of Art, 1990.

Feigenbaum, Gail. "Introduction: Art and Display in Principle and in Practice." In *Display of Art in the Roman Palace 1550-1750*, edited by Gail Feigenbaum, 1-24. Los Angeles: J. Paul Getty Trust, 2014.

Giustiniani, Vincenzo. *Discorso sopra la musica*. Archivio di Stato, Lucca, Fondo G.B. Orsucci 48 (olim O. 49).

Hammond, Frederick. *Music and Spectacle in Baroque Rome: Barberini Patronage Under Urban VIII*. New Haven and London: Yale University Press, 1994.

Hill, John Walter. *Roman Monody, Cantata, and Opera from the Circles around Cardinal Montalto*. Oxford: Clarendon Press, 1997.

Inventario de Quadri e Statue, 20 A. Parte IV, no. 8, Rome, Archivio di Stato, Casa Giustiniani, Busta 16.

Langdon, Helen. *Caravaggio: A Life*. New York: Farrar, Straus and Giroux, 1999.

Lavin, Marilyn, *Seventeenth-Century Barberini Documents and Inventories of Art*. New York: New York University Press, 1975.

Satkowski, Leon. "The Palazzo Pitti: Planning and Use in the Grand-Ducal Era." *The Journal of Architectural Historians*, 42 (December 1983): 336-349.

Tessin, Nicodemus the Younger. *Travel Notes 1673-77 and 1687-88*. Sources Works Collection, ed. Merit Laine and Börje Magnusson. Stockholm: Nationalmuseum, 2002.

Tortella, P.G. "Antiveduto Grammatica, Ottavio Leone e le musiciens du Cardinal Montalto," *Le Revue des Musees de France: Revue du Louvre*, 1 (2015): 24-31.

Treadwell, Nina. "The 'Chitarra Spagnola' and Italian Monody, 1589 to circa 1650." Master's thesis. Los Angeles, University of Southern California, 1995.

Tyler, James. "The Role of the Guitar in the Rise of Monody: The Earliest Manuscripts," *Journal of Seventeenth-Century Music*, 9 no. 1 (2003). <https://www.sscm-jscm.org/jscm/v9/no1/tyler.html>.

Veltman, Joshua Joel. "Prosody and Rhythm in the Post-Tridentine Reform of Plainchant." Ph.D. dissertation, The Ohio State University, Columbus, OH, 2004.

Waddy, Patricia. "Many Courts, Many Spaces." In *The Politics of Space: European Courts ca. 1500-1750*, edited by Marcello Fantoni, George Gorse, and Malcolm Smuts, 209-230. Rome: Bulzoni Editore, 2009.

Waddy, Patricia. *Seventeenth-Century Roman Palaces: Use and the Art of the Plan*. New York: The Architectural History Foundation and Cambridge: The MIT Press, 1990.

Waddy, Patricia. "Tessin's Rome." *Konsthistorisk Tidskrift*, 72 no. 1 & 2 (June 2003): 113-23.

Wazbinski, Zygmunt. *Il Cardinale Francesco Maria del Monte 1549-1626*, vol. 1. Florence: Leo S. Olschki Editore, 1994.

Weil-Garris, Katherine and John F. D'Amico. "The Renaissance Cardinal's Ideal Palace: A Chapter from Cortesi's *De Cardinalatu*." In *Memoirs of the American Academy in Rome 35: Studies in Italian Art History I: Studies in Italian Art and Architecture 15th through 18th centuries*, edited by Henry Al Millon, 45-119, 121-123, Rome, 1980.

Wolfe, Karin. "Caravaggio: Another *Lute Player*." *Burlington Magazine* 127 (July 1985): 450-452.

Sylphs Supporting Sylphs: Confronting Gender Binaries in the Ballet Canon

Christa St. John and Jamie A. Johnson
Utah Valley University

ABSTRACT

Ballet has a history of perpetuating gender binaries in pedagogy and performance. Twenty-first-century ballet is evolving to include more expansive gender expressions and identities. Many works from the classical ballet canon emphasize heteronormative relationships and represent females as chaste, unobtainable, and otherworldly. To contribute our voices to the evolution of gender in ballet, we reimagined a historic piece for an ensemble of undergraduate college students and conducted an institutional review board–approved study. In it, we explored how an all-female-identifying cast alters a work that seems to idealize cisgender relationships and a hegemonic male figure. We collected data generated by movement research, practitioner observations, and post-experience surveys. In the process, we confronted classic repertoire norms and historical gendering practices. As Linda Caruso Haviland (2013, 4, <https://www.pewcenterarts.org/sites/default/files/repetition-island-linda-caruso-haviland-final.pdf>) eloquently states, “There are no reconstructions of the past in the present that are ideology-free and all reconstructions construct a picture of the past that equally reflects what was and who we, as reconstructors and

recontexters, are.” Reimagining canonical ballets provides an opportunity to present historic works while supporting a spectrum of gender identities and expressions.

INTRODUCTION

Historically, ballet has perpetuated gender binaries in pedagogy and performance.¹ A review of the literature showcases how the binary has developed within the form. Training practices in ballet and roles in performance have traditionally been, and in some cases still are, based on the dancer’s sex assigned at birth and the social construct of male and female roles within the culture.² The perpetuation of performing gender through a binary (male/female) lens, to a certain extent, has been in place since ballet’s codification and professionalization. To that point, dance scholar Jennifer Fisher (2021, 337) writes, “Classical ballet as an art form has developed with fixed ideas about gender at its heart. Since its codification in seventeenth-century France, through its evolution in Europe, Russia, the United States, and elsewhere, ballet has reflected the culture(s) in which it developed, with the heterosexual duet as one of its most enduring aspects.” As ballet developed and women joined the professional ranks, ballet’s emphasis on heteronormative couplings has been perpetuated through the male/female *pas de deux*.³

¹ We, the authors, recognize that peoples’ understanding of gender varies. The authors’ use of the terms gender, gender identity, and gender expression align with the definition put forth by sociologist Dr. Carmen Henne-Ochoa (2022). Henne-Ochoa defines gender as, “the socially constructed roles, behaviors, activities, and attributes that society considers ‘appropriate’ for men and women. It is separate from ‘sex,’ which is the biological classification of male or female based on physiological and biological features. A person’s gender may not necessarily correspond to their birth assigned sex or be limited to the gender binary (woman/man).” Gender identity refers to, “all people’s internal, deeply felt sense of being a man, woman, both, in between, or outside of the gender binary, which may or may not correspond with sex assigned at birth.” Henne-Ochoa explains that gender identity is internal whereas gender expression is the “external manifestations of gender, expressed through a person’s name, pronouns, clothing, haircut, behavior, voice, and/or body characteristics.”

² Throughout this article, we use the terms “male” and “female” as they have been historically used in a ballet context. In this manner, “male” refers to male-presenting dancers who specialize in supportive partnering and *allegro* in classical ballet, whereas “female” refers to female-presenting dancers who specialize in pointe work in classical ballet. The authors recognize the limitations of these terms that do not encompass the full spectrum of gender.

³ When Googling “*pas de deux*” and “significance of a *grand pas de deux*,” a variety of definitions emerge that highlight romantic, heterosexual couplings. The top three examples we found define *pas de deux* and *grand pas de deux* as: “a dance for two people, typically a man and a woman.” (Google Search, s.v. “*pas de deux*,” accessed September 1, 2023, https://www.google.com/search?q=pas+de+deux&rlz=1C5GCEM_

Despite some challenges to heteronormativity and the growing recognition of gender identification beyond male or female in the contemporary ballet world, the gender binary is still ingrained in many training practices. “Training methods arguably do their part in hampering the evolution of gender expression in ballet. Although gender identity has been recognized as fluid in many cultures, only two manifestations dominate the ballet world, where classes, roles, costumes, and shoes have been designed specifically for either female or male dancers.” (Fisher 2021, 340). To that point, the dance writings of Michael Montoya illustrate further how ballet’s pedagogical traditions reinforce the gender binary. Montoya (2022) explains,

Dancers are often separated into ‘male’ and ‘female’ classes, and when in the same class, often trained in different skills and styles of movement. While female training primarily focuses on flexibility and feminine expression, male training features powerful athletic jumps and turns, and complicated sequences of both. Regardless of their gender or sexual identity, biological females are expected to be soft and delicate, and biological males to be strong and masculine.

The perpetuation of gendered training practices can lead to a limited view of the female role in ballet performance, primarily the image of the female dancer. Montoya (2022) describes, “...the image of the female dancer generally fits one of three molds: vulnerable waif, hypersexualized doll, or angry villainess.” The roles for dancers are further restricted in that, “choices in casting, choreography, staging, setting, and storytelling are almost exclusively heteronormative and are made to appeal to cisgender heterosexual audiences” (Montoya 2022).

Throughout ballet’s evolution, however, there have been outliers—artists whose work challenged heteronormative narratives and pushed

enUS966US967&oq=Pas+&aqs=chrome.0.35i39i650j46i340i433i512j35i39i650j69i64j69i57j69i60i3.879j1j4&sourceid=chrome&ie=UTF-8) and “a dance by two persons. (in classical ballet) a set dance for a ballerina and a *danseur* noble, consisting typically of an entrée, an adagio, a variation for each dancer, and a coda.” (Dictionary.com, s.v. “*pas de deux*,” accessed September 1, 2023, <https://www.dictionary.com/browse/pas-de-deux>), and finally, “*grand pas de deux* is effectively a suite of dances that share a common theme, often symbolic of a love story or the partnership inherent in love, with the dancers portraying expressions of affectionate feelings and thoughts between romantic partners.” (Google Search, s.v. “*significance of grand pas de deux*,” accessed September 1, 2023 [https://en.wikipedia.org/wiki/Pas_de_deux#:~:text=Grand%20pas%20de%20deux,-The%20Nutcacker%20\(2011&text=It%20is%20effectively%20a%20suite,and%20thoughts%20between%20romantic%20partners\)](https://en.wikipedia.org/wiki/Pas_de_deux#:~:text=Grand%20pas%20de%20deux,-The%20Nutcacker%20(2011&text=It%20is%20effectively%20a%20suite,and%20thoughts%20between%20romantic%20partners))).

beyond the gender binary. Although today much experimentation in this regard shows up in original, new works, some artists have challenged convention through choreographic reimaginings of historic ballets. For example, Matthew Bourne's wildly successful reimagining of *Swan Lake* (1995), in which Bourne recast the ballet with male (rather than female) presenting swans, helped pave the way for artists to experiment with gender in regard to the ballet canon. In the 21st century, artists such as Katy Pyle, the Artistic Director of Ballez, have been "reworking canonical ballets to incorporate queer themes and perspectives and by casting dancers with a variety of body types, dance trainings, gender identities, and gender presentations" (Alterowitz 2021, 133). Pyle (they/them), who describes herself as a lesbian choreographer, has reimagined full-length canonical ballets including *Sleeping Beauty* after Petipa and *The Firebird* after Fokine (Alterowitz 2021). Pyle's work, however, is the exception rather than the rule. Most ballet companies and academies still present historic ballets with predominantly heteronormative stories and gender binary representation.

Reworking canonical ballets provides an opportunity to question representation, promote inclusivity, and reflect current cultural values. To that point, dance journalist Sara Komatsu (2021) advocates, "Within the choreography and narratives of the classical ballet canon, there is certainly room to reevaluate how these works present and represent women and power dynamics between the sexes. Moreover, the ballet world must learn to let go of some of its rigidity and actively work to become a more inclusive and welcoming place." The literature reveals the embodiment of gender roles in the extant ballet canon invites reworking, reexamining, and reimagining.

MOTIVATION AND DESIGN DEVELOPMENT

As Co-Artistic Directors of Utah Valley University's Repertory Ballet Ensemble (RBE), a performing company comprising undergraduate ballet students, we sought to explore how gender is portrayed in a historic ballet by examining pedagogical, programming, and casting considerations.

Annually, RBE performs a mixed repertoire concert featuring classic and contemporary works. When deciding on a classic work for the 2021-2022 season, we hoped to stage excerpts from the historic ballet *Les Sylphides*, which is traditionally comprised of an all-female cast and one principal male dancer. A challenge presented itself when no male-identifying dancers auditioned for the company. We questioned whether we could stage the work without a male dancer and what the impact of that choice would be. Dance scholar Ann Daly (1987, 16) once referred

to ballet as “one of our culture’s most powerful modes of patriarchal ceremony.” If we stepped outside of the “dominant ideology” in ballet that “select(s) dancers on the basis of a classical ideal of beauty” and reinforces “traditional sex roles” and “hierarchical structures,” would there be space for this revisioning of gender roles? (Novack, 1993, 39). Simultaneously, we also wondered about the implications of not moving forward with the ballet, simply because there was not a student company member who identified as a specific gender. We felt that if we did not move forward with the reimaging, we would be setting the form backwards in terms of inclusion and equity and would not be creating space for society’s expanded understanding of gender as fluid and presentational. These questions led us to embark on a research-based case study.

We decided to reimagine excerpts of the ballet for an all-female-identifying cast and developed an Institutional Review Board (IRB)–approved study in conjunction.⁴ Because the original ballet was created in the hyper-cisgender world of the early 20th century, reimaging this work within the context of 21st-century higher education brings up some pedagogical quandaries. As with any choreographic reimaging, there are many aspects to examine. Dance scholar Linda Caruso Haviland brings up several considerations in her essay, “Repetition Island.” Haviland (2013, 4) highlights, “There are no reconstructions of the past in the present that are ideology-free and all reconstructions construct a picture of the past that equally reflects what was and who we, as reconstructors and recontexters, are.” Therefore, the original staging of this work was influenced by its own history and culture, and so too was our reimaging.

Our study was conducted at a large state university with approximately 40,000 students. An open-enrollment, commuter college, the institution draws primarily from the local area. The gender binary is predominant in the sociocultural context in which our university is situated. This institution is in a county where 72% of its population is affiliated with The Church of Jesus Christ of Latter-day Saints (Toone and Walch 2021). The demographic composition impacts local culture and, more specifically, people’s understanding and expression of gender roles as informed by their religion. In reflection of Linda Caruso Haviland’s (2013) thoughts about reconstructions and culture, this restaging is not just about the reimagers, it also involves the sociocultural aspects of participants within the reconstruction. Given that

⁴ Throughout the remainder of the article, we refer to female-identifying students as female to reflect how the students self-identified.

knowledge, we had to be thoughtful about how we moved forward with this project.

Our reimagining embraces the gender spectrum, which reflects a data-indicated generational shift in perspective. A Fusion Millennial poll (2015) of adults aged 18–34 years in the USA found that the majority see gender as a spectrum, rather than a man/woman binary. In a small way through this study, we hope to expand local cultural understanding of the gender spectrum in ballet.

RESEARCH METHODS & PROCEDURES

The IRB-approved study design was qualitative in nature. Data for the study were generated by physical, experiential movement by participants, researcher observations, and post-experience surveys. Participants were drawn from members of a university student ballet performing ensemble. Ensemble membership is determined by audition the first week of the Fall semester and is accessible to serious ballet students who show a high level of talent and technical achievement. Ensemble members were selected by the five full-time ballet faculty at the university. Participants rehearsed excerpts of the ballet as a part of their coursework in Fall 2021 and Spring 2022. Students rehearsed Mondays through Fridays from 3:00–4:45 pm and dedicated approximately 50 hours of rehearsal and performance time to the reimagined work. Participants responded to a post-experience Qualtrics survey after the completion of the public performances of the work. Most participants took an hour to complete the survey.

The study was conducted by the authors who are college professors who joined academia after professional performing careers in ballet that spanned over a decade each. One of us has direct ballet lineage to Fokine, having performed the original ballet under the direction of Dorothy Daniels Lister, who performed the work regularly with the renowned Ballet Russe de Monte Carlo. Our embodied histories with the original ballet and our international performing experience influenced the reimagining of the work.

Experiential Movement

In our initial choreographic reimagining of several excerpts from *Les Sylphides*, we sought to find a balance between our embodied histories with the original staging of the work and how to reenvision it for the bodies in the room. As with many classic ballets, this work includes a significant amount of supportive partnering and virtuosic movement traditionally reserved for male dancers. We recognize that we are not the first to reimagine a historic ballet to include same-gender

partnering, but it is the first time we have attempted this at our institution. As much as the students, we were learning through this process.

Four primary methods were employed to reimagine the role of gender in excerpts of the ballet for our all-female cast:

1. We changed some of the male and female partnered sections to solos for female dancers.
2. We had a female dancer perform solo choreography usually performed by a male dancer.
3. We reworked some of the traditional male and female *pas de deux* movements (henceforth referred to as “supportive partnering”) to be performed as a side-by-side duet with two female dancers.
4. We had two female dancers perform supportive partnering in the style of the original male and female *pas de deux*.

Throughout the choreographic modifications, we attempted to maintain the style of the original steps.

During the rehearsal process, for the most part, modifications were embraced by the students; however, the reimagining was not without challenges. The sections in which we attempted to keep the supportive partnering stylistically similar to the original version elicited the most divergent student response. It was in these sections that we were most directly confronting traditional gender roles and hierarchical structure embedded in ballet training and performance.

In traditional *pas de deux*, the male often takes the perceived lead. The male will offer his hand to guide the female’s movements, initiate turns through the torque of his hands, propel the female into space with strong supported lifts that go over his head, and serve as a stabilizing force for dramatic leg extensions by the female. In response, the female demurs with delicate acquiescence. This perception of traditional *pas de deux* work perpetuates the view that “the masculinity and femininity that is enacted through the bodies of male and female dancers can be seen as a reiteration and reproduction of cultural norms that assign strength and independence to men and weightlessness and passivity to women” (Aalten 2004, 270). As lead researchers of this study, we embrace the views forwarded by dance scholar Sally Banes (1999, 3), who offered up the idea that there is a “much more complex range of representations than has previously been suggested.” Reworking a traditional male & female *pas de deux* offers opportunities for “different femininities” (Aalten 2004, 270) to emerge that counter the dominate narrative of weightless passivity. Furthermore, our views on gender as a performative act align with those of scholars West and Zimmerman (1987), Butler (1990), and Aalten (2004) amongst others. Viewing gender as a performative act

opens the door in ballet for supportive partnering to be enacted by any dancer.

In rehearsals, we worked on basic partnering technique and experimented with different approaches. Our experimentation revealed that the students had some preconceived notions about partnering, and many had limited to no experience working with a partner in a supportive (traditionally male) role.

We designated two casts of principal dancers for the ballet: Cast A and Cast B. The two casts approached the work from different perspectives. The principal dancers in Cast A seemed hesitant to explore the traditionally male partnering role. They appeared to wrestle with both dancers' desire to execute the traditionally female choreography. Cast B openly explored same-gender partnering in a classical context. The dancers practiced the partnering sections on their own and were even open to experimenting with a supported *penché* with both dancers *en pointe* (Figure 1). This is an especially challenging movement when both dancers are balancing on their toes. It was originally designed to be executed with the male dancer standing flat-footed.



Figure 1: Cast B supported *penché*, photo credit: Simeon Mismash.

Throughout the rehearsals, we continued to encourage Cast A to work on the material and experimented with different approaches and modifications. As we got closer to the performances, however, we recognized that just because we were excited about this experiment, did not mean that all the students were inclined to embrace this reimagining, and some may even fundamentally disagree with our approach.

It became clear we needed to find a compromise. We provided Cast A with the opportunity to suggest a modification they felt confident performing. They suggested an adjustment to the choreography in which they both supported each other rather than having one dancer embody the traditionally male role (Figure 2).



Figure 2: Cast A supported penché, photo credit: Simeon Mismash

The divergent responses of the two casts led us to create two versions of the same section. By having females partner females in both versions, even with the differences in execution, we were stepping outside of the heteronormative expectation for classical ballet and disrupting pedagogical traditions by asking females to perform traditionally male steps. As one might expect when disrupting tradition, we were met with some resistance.⁵

Survey

After the performance and rehearsal process, we surveyed the students about their experience. Participants responded to several background and demographic questions as well as three experiential questions. To mitigate researcher subjectivity, questions were constructed in open-ended ways to allow for rich descriptions from the participants. We also distanced ourselves from the data by using systematic coding techniques. These coding techniques allowed various

⁵ During rehearsals for a contemporary original ballet choreographed by St. John later in the academic year, the same dancers in Cast A, who were resistant to partnering in the context of the classic work, appeared more open to same-gender partnering in the contemporary work. We are unsure whether this demonstrates a shift in perception or perhaps was a result of the more common occurrence of same-gender, weight-sharing partnering in contemporary movement vocabulary.

themes to emerge. The coding process focused on in vivo and descriptive coding (Saldaña 2013), and data were collected using a Qualtrics survey. The survey did not record personally identifying information (e.g., respondents' names, respondents' IP addresses, location data, or contact information) to keep responses anonymous, and students were provided an informed consent document prior to volunteering to participate.

RESEARCH OUTCOMES

The survey results were as follows. The survey was completed by 12 respondents, who all identified as female. The largest contingent of dancers stated they had 13–16 years of ballet training, with some experience doing partnering work. The open-ended questions garnered rich responses. Students' responses exhibited an understanding of the historical context of the original ballet as well as the impact that the alternate casting had on the reimagined work. One dancer wrote in response to the question, "From your perspective, how does an all-female-identifying cast alter the meaning of *Les Sylphides*?"

A big part of romantic ballets was the dynamic between men and women....So that exploration of creating an homage to romantic ballets, one of those core pillars of portraying heterosexual relationships was removed with the all-female cast....The idea of the romantic era ballets was still achieved through the stylistic way of using the ballet technique, the costumes, music, and lighting.

This dancer's response reflects many of the respondents' remarks. In the end, students recognized that a change occurred and that it impacted peoples' understanding of the work, but as a reimagining, they felt it honored romantic era ballets.

In response to the question, "How does performing or observing female-identifying dancers executing masculine actions, such as *port de bras*, partnering, and *allegro*, alter your experience of the work?" students had lively responses:

It gives it a very strong female presence as opposed to 'and here's a bunch of women flocking around a man.'

I think it is empowering to see that a female can partner another female in the classical world of ballet.

I performed a variation as a solo that is originally done as a duet between a man and a women. To me, it was much more special as a solo. As I was dancing it felt strong, powerful, and beautiful. But if I were to have danced it with a man it most likely would have felt more like I was a small woman that needed the help of a man to perform steps that I certainly can do myself.

Student responses seem to indicate they experienced or witnessed a sense of strength in having female dancers perform roles that had not previously been accessible to them. Some students in this study felt empowered and powerful when performing or watching other students perform “masculine” actions. Students appeared motivated to explore how they could physically take up space and command the stage. The responses seem to align with the words of columnist Maddie Pettit (2019) who stated, “Women are strong and independent, and men are comfortable embracing beauty; ballet, as a form of art, should reflect these more inclusive ideas instead of continuing to refute them.” By casting all-female identifying dancers in our reimagining and providing opportunities to perform movements traditionally performed by men, we were able to expand gender roles within this work.

Although it seems that many dancers were pleased with the final result of the ballet, there were some growing pains in the process. Some respondents remarked:

[It] made me feel a little bit uncomfortable. I did not necessarily love seeing a women execute masculine actions, but it did turn out better than I thought it would.

Observing the female-identifying dancers executing the traditionally masculine actions provided a few challenges ... females are typically not trained in partnering the way that men are. This meant that the dancers doing the typically male partnering part had to work extra hard to quickly learn the techniques that go along with that job.

The respondents’ discomfort and challenges in acquiring the new skills necessary to complete the performance tasks highlight how this research is confronting traditional pedagogical and performance methods and values. The student responses are also likely a result of historical gendering within their pedagogical training. Students in this study who were tasked with learning the supporter role felt they had limited experience lifting and supporting another dancer. The strength and counterbalancing techniques necessary to serve in a supportive role

had not been a rigorous part of their training, so dancers were learning the techniques throughout the rehearsal process as opposed to being exposed to those ideas earlier.

Beyond the technical challenges, some students appeared to wrestle with engrained gender binaries in ballet and struggled with two female dancers performing partnering in a manner that historically has been reserved for heterosexual couplings. Student responses and practitioner observations indicate that some participants were challenged with the potential shift in the heteronormative gaze to, perhaps, one of homonormativity. The reimagined choreography was not necessarily amorous in nature, but, depending upon one's perception, it may have been interpreted that way. The homonormative gaze stands in opposition to the heteronormative, cisgender representations audiences have come to expect and may have been a factor in students' feelings of discomfort.

Our final experiential question asked, "What value does this reimagining have for you as a ballet student in higher education?" Dancers replied,

[This reimagining provided] the ability to still perform classical works without a male dancer present.

It showed me that even when a limitation presents itself, we can rise above it and exceed expectations.

[It] provided me with insight into how to approach recreating classic works.

This really gives me an eye-opening experience. I have always believe[d] in needing to stick with the traditions and follow the rules when it comes to classical ballets. You are allowed to re-shape and reimagine things...

It gave me options for future works and opened my mind to new ideas of learning and teaching.

These responses indicate that the shift to an all-female-identifying cast led the dancers to see new opportunities and challenged some existing perceptions regarding gender roles in ballet. The student voices in this study highlight the advantages and challenges of confronting gender binaries within the ballet canon. Society as a whole is shifting to embrace a spectrum of gender identities. By offering alternate casting, we supported more inclusive practices and facilitated alternative narratives to emerge. We expanded the parameters of what it means to

be a female in ballet and moved beyond the doll, the villainess, and the waif (Montoya 2022).

CONCLUDING THOUGHTS

As Co-Artistic Directors of a collegiate dance ensemble, we disrupted convention by casting females in a traditionally male role in a reimagining of a classic ballet. In a two-part IRB-approved study, we confronted historical gendering practices in ballet performance and pedagogy by eschewing the gender binary within the work. Reimagining the canonical ballet provided an opportunity to step outside of embedded heteronormativity, facilitated the development of students' technical and performance skills, and empowered the participants by challenging them with movement not previously emphasized in their training. Despite some resistance and discomfort from the students during the rehearsal process, those who engaged with the material gained a range of valuable skills that are highly relevant in today's educational and performance contexts. Furthermore, the process highlighted the significance of embracing the power of femininity as a potent force in promoting gender equity. Incorporating a more diverse range of dancers in roles that have traditionally been assigned based on historical constructs of gender in ballet presents an opportunity for the art form to not only reflect the current cultural climate but also shape it. By broadening the representation of dancers whose gender identity differs from the original casting in historic works, ballet can embrace inclusivity and increase equity in the field. This shift has the potential to transform the way in which ballet is perceived and experienced, which in turn can make it more accessible and relevant to a wider range of audiences.

The primary areas of investigation in this study are rich for further exploration. Confronting heteronormative biases, expanding who can perform roles within canonical ballet, and examining the impact of gendered training are important topics within the ever-evolving idiom of ballet. The preliminary findings of this study have encouraged us to make some modifications to our pedagogical and choreographic practices moving forward. Upon completion of this study, we have been incorporating more supportive partnering into course curriculum, so students are exposed to these techniques prior to a rehearsal setting. We continue to shift the culture to embrace the spectrum of gender through our use of pronouns, open gender casting, and expansive partnering practices. We look forward to seeing how we and other researchers can continue to address these complicated issues to support students' educational journeys and promote inclusive practices in pedagogy and performance.

REFERENCES

Aalten, Anna. 2004. "The moment when it all comes together." *European Journal of Women's Studies*, vol. 11, no. 3: 263–76. <https://doi.org/10.1177/1350506804044462>.

Alterowitz, Gretchen. 2021. "Feminist practices in ballet: Katy Pyle and Ballez." In *The Oxford Handbook of Contemporary Ballet*, edited by Kathrina Farrugia-Kriel and Jill Nunes Jensen, 128-46. New York: Oxford University Press.

Banes, Sally. 1999. *Dancing Women: Female Bodies Onstage*. London: Routledge. <https://doi.org/10.4324/9780203344347>.

Butler, Judith. 1990. "Performative Acts and Gender Constitution." In *Performing Feminisms: Feminist Critical Theory and Theatre*, edited by Sue-Ellen Case, 270-83. Baltimore, MD: Johns Hopkins University Press.

Caruso Haviland, Linda. 2013. "Repetition island: Some thoughts on restaging, reconstruction, reenactment, re-performance, re-presentation, and reconstruction in dance." Philadelphia, PA: The Pew Center for Arts & Heritage. <https://www.pewcenterarts.org/sites/default/files/repetition-island-linda-caruso-haviland-final.pdf>.

Daly, Ann. 1987. "Classical ballet: a discourse of difference." *Women & Performance: A Journal of Feminist Theory* vol. 3, no. 2: 57-66. <https://doi.org/10.1080/07407708708571104>.

Fisher, Jennifer. 2021. "Gender progress and interpretation in ballet duets." In *The Oxford Handbook of Contemporary Ballet*, edited by Kathrina Farrugia-Kriel and Jill Nunes Jensen, 337–54. New York: Oxford University Press.

"Fusion's Massive Millennial Poll." 2015. Scribd. Accessed November 8, 2023, at <https://www.scribd.com/document/254470588/Fusion-s-Massive-Millennial-Poll>.

Henne-Ochoa, Carmen. 2022. "DEIJ glossary." *Connecting Across Difference: Gender*, workshop at Utah Valley University. August 19, 2022. Unpublished PDF.

Komatsu, Sara. 2021. "Pas de deux: sexism and the gender binary in ballet." *The Harvard Crimson*. February 9, 2021. <https://www.thecrimson.com/column/backstage-at-the-ballet/article/2021/2/9/sara-column-pas-de-deux-sexism-and-the-gender-binary-in-ballet/>.

Montoya, Michael. 2022. "Gender and sexual identity expectations in dance and their effects on LGBTQIA+ dancers." *NDEO Behind the Curtain Blog*, March 22, 2022. <https://www.ndeo.org/Learn/Behind-the-Curtain-Blog/ArticleID/150/Gender-and-Sexual-Identity-Expectations-in-Dance-and-Their-Effects-on-LGBTQIA-Dancers>.

Novack, Cynthia J. 1993. "Ballet, Gender and Cultural Power." In *Dance, Gender and Culture*, edited by Helen Thomas, 34–49. London: Macmillan.

Pettit, Maddie. 2019. "The problem with gender in dance." *Medium* (blog), December 8, 2019. <https://medium.com/gbc-college-english-lemonade/the-problem-with-gender-in-dance-122d4d68fb75>.

Saldaña, Johnny 2016. *The Coding Manual for Qualitative Researchers*, third edition. Los Angeles, CA: Sage Publications.

Toone, Trent, and Tad Walch. 2021. "Which county has the second-highest concentration of Latter-Day Saints? Hint: it's not in Utah." *Deseret News*, July 8, 2021. <https://www.deseret.com/faith/2021/7/8/22569016/which-county-has-the-second-highest-concentration-of-latter-day-saints-hint-its-not-in-utah>.

West, Candace, and Don H. Zimmerman. 1987. "Doing gender." *Gender and Society* vol. 1, no. 2: 125–51. <https://doi.org/10.1177/0891243287001002002>.

Towards an Invention of Style: Encoding Aspects of the 20th-Century Post-Tonal Tradition for Use in Contemporary Classical Solo Piano Improvisation

Evan B. Whitfield

Abstract

The innovations produced from the evolution in Western musical practice during the early 20th century coincided with a decrease in the continuation of 19th-century classical improvisation traditions. This phenomenon coincidentally negated the legitimate development of 20th-century classical piano improvisation. As the modern composer (e.g., Schoenberg, Stravinsky, Debussy) began profound explorations away from the late 19th-century Romantic tonal tradition, advancements in 20th-century Western piano improvisation eventualized from the avant-garde movements in free-jazz and the works of serialist and indeterminate post-modern composers after 1945 (e.g., Cage, Stockhausen, Berio). The inevitable musicological question is: what would early 20th-century classical piano improvisation have sounded like, if it had been allowed to flourish, adapting to a new environment of musical modernity from 1900 onwards? From my background as a

contemporary improvising pianist, I proposed an experiment of purposeful programming, with the attempt to answer this fundamental, historical quandary. Akin to a computer software engineer, I began by encoding the most compatible musical techniques associated with the pioneering efforts of the post-tonal 20th-century tradition. These were then linked with a selection of established techniques of keyboard improvisation. This paper will present a successful synthesization of early 20th-century compositional techniques into an innovative codex for a new model of contemporary classical piano improvisation.

The innovations produced from the evolution in Western musical practice during the early 20th century coincided with a decrease in the continuation of 19th-century classical improvisation traditions.¹ This phenomenon coincidentally negated the legitimate development of 20th-century classical piano improvisation. As the modern composer (e.g., Schoenberg, Stravinsky, Debussy) began profound explorations away from the late 19th-century Romantic tonal tradition (e.g., Liszt, Strauss, Wagner), advancements in 20th-century Western piano improvisation eventualized from the avant-garde movements in free-jazz and the works of serialist and indeterminate post-modern composers after 1945 (e.g., Cage, Stockhausen, Berio). The inevitable musicological question is: what would early 20th-century classical piano improvisation have sounded like, if it had been allowed to flourish, adapting to a new environment of musical modernity from 1900 onwards? From my background as a contemporary improvising pianist, I proposed an experiment of purposeful programming, with the attempt to answer this fundamental, historical quandary.² Akin to a computer software engineer, I began by encoding the most compatible musical techniques (those that elicited a high degree of probable synthesization for improvisational use) associated with the pioneering efforts of the post-tonal 20th-century tradition such as polymodality, octatonicism, polymeter,³ and the adaptation of the 19th-century sonata form into cyclical and malleable structures facilitating motivic transformation (e.g., Ravel). These were then linked with a selection of established

¹ See Després et al. 2017.

² This paper is a documentation of my research during fall 2021 to summer 2022, while a PhD student enrolled in the Creative Practice Research Degree Programme at Trinity Laban Conservatoire of Music & Dance in Greenwich, London, UK.

³ The nature of the scholarly work defining each of these subjects is exhaustive; explaining the history of each one is beyond the scope of this research paper. For a thorough analysis of selective 20th-century compositions discussing each of these salient musical innovations, see Berry 1987, Kostka and Santa 2018, Persichetti 1978, and Strauss 2000.

techniques of keyboard improvisation (past and present) such as parallelism/planing, contrapuntal canonic invention, polyharmonic chordal manipulation, chromatic transpositional modulation, and thematic metamorphosis. The next step involved constructing a new type of form, modeled from the modernistic expansions of the early 20th century, as well as the use of graphic score realizations, a late 20th-century and early 21st century invention.⁴ The final step was the creation of thematic material—the genesis for the synergy of all the elements—from which an improvised development would transpire. A practice-as-research methodology⁵ was used to document the different stages of myself being “programmed.” This paper will exhibit—by documentation and explanation of my application of selective 20th-century modernisms by specific composers—a successful synthesization of those techniques into an innovative codex for a new model of contemporary classical piano improvisation.⁶

Historical Background

This research investigated the creation of a 20th-century tradition of classical piano improvisation, extending upon the previous 17th, 18th, and 19th century classical improvised traditions. A large body of scholarly research exists on the improvisational expertise of pianists, organists, and composers such as Bach, Handel, Beethoven, Mozart, Franck, Bruckner, Saint-Saens, Mendelssohn, Clara Schumann, Chopin, and Liszt⁷ (Czerny, Hummel, and Falkbrenner also wrote extensive treatises about 19th-century piano improvisation).⁸ However, as Western classical improvisation phased out towards the end of the 19th century,⁹ evolving

⁴ See Bailey 1993, Bhagwati 2013, Brindle 1987, and Neeman 2014.

⁵ For a clear definition of practice-as-research’s origins, methodology, and applications to contemporary creative academic research, see Nelson 2006.

⁶ Leading contemporary pianists who have recorded and/or performed some form of contemporary improvised classical piano music, with or without a specific jazz influence or jazz-inspired context, include Marilyn Chrispell, Keith Jarrett, Brad Mehldau, Myra Melford, Robert Levin, David Dolan, Noam Sivan, and Gabriela Montero.

⁷ See Azzara 2002, 175–176.

⁸ For an in-depth discussion regarding a comparison of all three, see Edin 2008. Edin also investigates how aspects of 19th-century improvisation can be applied towards the creation of modern music.

⁹ Some scholars believe it ended even earlier, such as Christopher Azzara: “While some 20th-century and 21st-century classical composers have included improvisation sections in their pieces, improvisation’s role in Western classical music has decidedly declined since the middle of the 19th century” (Azzara 2002, 176). See also Gooley, 2018, 1–15, Hamilton 2008, chapters 1, 2, and 3, and Phillip 2004, chapters 1 and 2, for important insights explaining the reasons for the decline of piano improvisation towards the end of the 19th century.

forms of performance practice and the introduction of modern music focused less on the creation of spontaneous material and more on the insistence of preserving new scores.¹⁰ Most importantly, the invention of jazz circumscribed many of the classical traditions that had previously allowed improvisation to flourish as a concert artform, including the extended Romantic cadenza-fantasies of Liszt¹¹ and the 19th-century practice of improvised preludes.¹² Gradually, as modern music became confronted with the emergence of the avant-garde in the mid-1950s, the practice of Western piano improvisation focused either on indeterminate and aleatoric procedures (e.g., Cage, Feldman, Cardew)¹³ or highly abstract free-improvisation, typical of the post-World War II atonal period.¹⁴

Existing Research

The documentation of evidence in this paper for a new model of contemporary classical piano improvisation does not rule out the possibility of the existence of ad hoc representations of Western 20th-century post-tonal classical improvisation, such as modern deviations from extant European organ improvisation traditions.¹⁵ However, much of the scholarly literature covering modern improvisational innovations, styles, and practices during the previous century are considerably bereft of any specific musicological examples. In Derek Bailey's seminal work on improvisation, *Improvisation: Its Nature and Practice in Music* (1993), no chapters exist on 20th-century Western classical improvisation. Instead, Bailey devotes sections to confirm the continuation of the tradition of French and German liturgical organ improvisation and the reasons for its preservation as a viable form of Western improvisational practice:¹⁶

The main reason for the survival and continuous development of improvisation in organ playing, when throughout the rest of European classical music improvisation was being neglected or

¹⁰ For a summary of how notation limited improvisation in the early 20th century, see Neeman 2014, 10–11.

¹¹ See Hamilton 2008, 42–54.

¹² See Goertzen 1996, Gooley 2018, 5–8, and Hamilton 2008, 29.

¹³ For an excellent source on these composers and their contribution to the post-1945 avant-garde movement, see Brindle 1987.

¹⁴ See Neeman 2014, 8–45.

¹⁵ There may very well be existing documentation on a group of musicians, artists, or composers who have experimented with the research and ideas discussed in this paper.

¹⁶ See Gooley 2018, 14.

suppressed, is probably the adaptability and purely practical inventiveness required of any church organist in his working situation, a situation in which the creation of music is a necessity. (Bailey 30)

A current body of scholarly work is documenting and analyzing the evolution of 19th-century organ improvisation practice, as it seems to be the only true form of Western tonal (and possibly post-tonal) classical improvisation that does not rely on idiomatic, stylistic influences for its production.¹⁷ Recently, cognitive psychological studies of Western classical music performance have shown a general lack of contemporary classical improvisation¹⁸ and a “relative absence of improvisation in classical music training” (Després et al. 2017, 2). In this light, my research is a welcome contribution to a body of work that has yet to be theoretically and practically realized.

Critical Modeling Strategies

David Dolan writes that “models of improvisation tend to work on the relationship between three main factors: the knowledge base (comprising both the musical elements and instrumental mastery); the referent (representing a chosen constraint of the extemporisation); and the different manipulations and operations on the musical material” (Dolan 2005, 109). In my model, the referent—a term I have borrowed from Jeff Pressing’s seminal research on cognitive processes in improvisation (Pressing 1984, 346)—represents anything that offers a preconceived deterministic component during the improvisation, such as the use of classical and baroque dance forms as a formalized structural imposition. Currently, research studying the cognitive behavior of improvisation tends to favor analyses of jazz music. Thus, any jazz-inspired modeling strategies would need to be translated from the jazz idiom into a modern classical context. One of the most important components of my research is the insistence on a suitable application of form. Form is a necessity that allows for the performance behaviorisms of any improvising soloist to be realistically projected and contained; this architectural boundary prevents the inevitable result of complex improvised music dissolving into subterranean chaos. In a practical sense, my concept does have a distinct parallel with the jazz tradition and its 12-bar blues and 32-bar song form. Contrastingly, free music grapples

¹⁷ For a Swedish perspective on 20th century organ extemporization theory and techniques, see Tandberg 2008.

¹⁸ See Dolan et al. 2013.

simultaneously with the formation of structure and syntactical parameters—i.e., motives, harmonies, timbres, and texture—which are loosely uncontrolled in patterns of indiscriminate uncertainty. This obfuscation leads the improviser into a grey area of disorganized confusion and lack of control. Practicing contemporary classical improvisation from within a hierarchical system has proven to be beneficial because classical and baroque forms such as rondo, sonata-form, minuet, theme-and-variations, passacaglia, and sarabande serve to regulate the tendencies towards an uncomfortable density of hyper-harmonic, hyper-developmental musical situations.

Outline of Model—Sonata Form

Preliminary research commenced in London, UK, in about September 2021, with the goal to compose a structured piece for solo piano improvisation that would incorporate the compositional techniques and stylisms so reminiscent of early 20th-century modern classical composition—polyrhythm, polymeter, polymodality, and others. After much creative exploration, research, and consultation with my academic supervisors, I began to work on an idea for a Sonata for Piano Improvisation, a formal piece of music with precomposed sections and materials, structured in the same vein as perhaps one might imagine a virtuosic, Lisztian symphonic tone-poem for piano: the envisaged gestalt would be a triumph of my creative will over the elements, a composition for improvisation that would challenge any performer–improviser to interpret its mystical properties. My creative endeavors resulted in a collection of four movements resembling a classical sonata:

1. a first movement outlining the typical exposition, development, and recapitulation sections;
2. a slower, contrasting free-play second movement;
3. a Baroque-inspired dance suite for a third movement; and
4. a reunification-of-thematic-content fourth movement.

I named this piece *Sonata for Improvising Piano*, No. 1.¹⁹

¹⁹ To view the *Sonata for Improvising Piano*, No. 1 (2022) in its entirety, visit the author's LinkedIn webpage of the posted score at: [https://www.linkedin.com/posts/ evanwhitfield_sonata-for-improvising-piano-no-1-2022-activity-7022654537064742912-8H1Z?utm_source=share&utm_medium=member_desktop](https://www.linkedin.com/posts/evanwhitfield_sonata-for-improvising-piano-no-1-2022-activity-7022654537064742912-8H1Z?utm_source=share&utm_medium=member_desktop).

Comprovisation vs. Structural Improvisation

The inception for *Sonata for Improvising Piano*, No. 1, developed from several strands of creative threads running in contradictory fashion. Much of my early work involved strict compositional processes, because my intention was to ferment several thematic, cyclical-motivic axes that would serve to organically structuralize the entire sonata. Surprisingly, this dialectic resulted in two distinct compositions being eventualized: nine movements for piano entitled *Épisodes pour le piano* (2021, 2022) and the *Sonata for Improvising Piano*, No. 1 (2022). Most of the work for both projects overlapped, and because of the practice-as-research methodology of recording written observations in daily journals, I was able to concretely separate the absolutist composed work from the composed-work-for-improvisation. An apt term that could be used to describe my sonata is “comprovisation,” a portmanteau of composition and improvisation, conjointly coined by several scholars, composers, and authors during the first two decades of this century. Much of the credit for this term should be given to Sandeep Bhagwati, who first gave academic credence to its practical use in 2013 in an essay published in *Sound and Score: Essays on Sound, Score and Notation* (Bhagwati 2013, 165-177). Phillip Thomas, Professor in Performance at the University of Huddersfield, UK, produced a collection of piano improvisations and compositions in 2007 entitled *Comprovisation*. In the accompanying liner notes, he states that the term “suggests more what the music is *not* rather than defining what it is” and that it signifies “improvisations upon ideas from a fixed composition” (Thomas 2007). There is an abundance of applicable meanings for this word, and any recent academic search on the internet will reveal suitable references, including a thesis entitled *What is Comprovisation?* (Dale 2008), wherein Roscoe Mitchell, the idiosyncratic, virtuosic, and avant-garde improvising instrumentalist of Association for the Advancement of Creative Musicians fame, contributes an alternate term instead of comprovisation, *scored improvisation*:

...scored improvisation means: you’re actually giving the improviser the materials that are going to be improvised. And what this does is it helps the improviser with developing a concept of being able to have materials in your head, and different ways of arranging it. (Dale 11)

Although this application of comprovisation would be apropos to my work, I prefer the term *structural improvisation*, because it resonates with my conviction that architectonic form is a necessity of the function

of my creative endeavors to offer performances without superlative evocations. Malcolm Goldstein, the American-Canadian composer, violinist, and improviser, has also ventured forward his own *modus operandi* of incorporating aspects of structured improvisation into his compositions. His self-published treatise on improvisation, *Sounding the Full Circle* (1988), contains descriptions of his compositions and the methods he uses, such as the adaptation of the Baroque figured-bass embellishment style in his *Cascades of The Brook: Bachwasserfall* (1984):

The music is...an extension of the first movement of Bach's Sonata in G minor for Violin Solo... The notation of the original manuscript serves as the basis for the notation of the chamber orchestra realization. It is transformed through collage and other graphic devices, overflowing with nuances and implications, as it elaborates upon the melodic and harmonic structure of the original prelude. (Goldstein 42)

Thus, improvisation can exist cooperatively in a composition if the integration is adequately structured to a homogeneous form. This integration requires some adherence to organically constructed rules and parameters set up by the composer, and alternative notation such as graphic scores is one method that can produce cohabitational constructs. As George E. Lewis writes, "the most common Eurological method of providing these rules is the construction, by a composer, of autonomous, often culturally ad hoc systems of specified musical behavior options" (Lewis, 115). However, a critical question that arose during my research was: can too much structure destroy the possibility for spontaneity in my own solo improvisation work?

Jeff Pressing: Graphic Scores, Practice and Skill Rehearsal, Feedback (Proprioceptive) and Feedforward, The Referent, and Improvisation vs. Composition

My decision to use graphic score realizations evolved from my codependence as a visual learner; seeing the work can offer an alternative interpretation of the theoretical and philosophical underpinnings. The graphic overlay is a unique way of showing all of the processes and instructions for the performer at once. Whether a two-dimensional or three-dimensional geometric perspective is used, a visual representation of musical objects is a unique foreground in which the improviser can envision the landscape, a type of musical pre-cognition. My study of Jeff

Pressing's diagrammatic renderings of improvisational processes in Euclidian space²⁰ have been a major influence for my graphic scores that precede each of the sonata's four movements.

Pressing's models for improvisation evolved from his extensive work in the 1980s reconciling 20th-century physiological and neuropsychological research of how muscle memory/kinesthesia, the central nervous system, and cognitive functionality/conscious monitoring work together to create the ability to improvise. In order for contemporary classical improvisation to exist as a relevant and fresh performance practice, it must be practiceable: meaning, it must have parameters that allow for the performer to prepare and practice its thematic contents to achieve optimum conditions for "behavioral novelty" (Pressing, 1988, 136). Pressing writes:

For improvised performance that aims at artistic presentation...practice must attempt to explore the full range of possible motor actions and musical effects, to enable finger control and the internal modelling of discrepancies and correction procedures including feedforward. (Pressing 136)

Pressing notes that with extensive "skill rehearsal," an improviser changes from "controlled processing" to "automatic motor processing," leading to "automaticity," a comfortable plane of improvisational freedom wherein muscle memory feedback and kinesthetic awareness are heightened due to a lack of "conscious monitoring of motor programmes" (139). The reason, Pressing argues, why practicing improvisation is so important, is that it reduces the level of real-time cognitive processing that is normally involved in learning a newer form of performance practice, resulting in "an abstraction to greater and greater generality of motor and musical controls to the point where highly variable, often *novel specific* results can be produced based on the automatic use of *general*, highly flexible and tuneable motor programmes" (140, my italics).

The concept of feedback is used by Pressing to describe the in-the-moment-error-reduction-process of most improvisers who can self-evaluate their improvisational flow midstream. The continuous cognitive monitoring of produced events enables critical decision-making for future events:

²⁰ See Pressing, "Improvisation: Methods and Models," 158–159, specifically Fig. 7.2 and Fig. 7.3.

...ideas are generated and realized into sound via technique. This produces continuous aural and proprioceptive feedback which allows continuous evaluation on the basis of which the current ideas are either repeated, developed, or discarded. In this way a long-term improvisation can be built up. (Pressing 1984, 353)

Alternatively, the term *feedforward* can be interpreted as anticipating or projecting future sound events before they happen. It is very similar to Ran Blake's concept of Third Stream ear training: the ability to develop long-term aural memory that is used to "hear" an improvisation as it progresses through time.²¹

For an improvised behavior to be self-organized within a objective structure, it must have some kind of parametric commonality, a unification tool that allows not for the grandest expressive freedom imaginable, but for a limitation of expressive devices to ensure coherence, such as a *referent*, "an underlying formal scheme or guiding image specific to a given piece, used by the improviser to facilitate the generation and editing of improvised behavior on an intermediate time scale" (Pressing 1984, 346). A referent can be "...a musical theme, a motive, a mood, a picture, a structure in space or time, a guiding visual image...a story, an attribute...any coherent image which allows the improviser a sense of engagement and continuity" (346). In my own improvisational practice, I have begun working with graphic, two-dimensional Euclidean "images" and composed harmonic and thematic material to be the "seeds" or referents for a neoclassical development concept in my *Sonata for Improvising Piano*, No. 1. Noting a correlation between improvisational practice and compositional styles preserved by musicology (assuming both a Western and a non-Western context), Pressing writes:

All referent-guided improvisation systems...stand in clear relation to a parallel repertory of compositions. That is, each such improvisation tradition has an associated group of devices used for development of ideas or seeds and those devices are...very similar to those of the allied compositional practices. (Pressing 1984, 350)

²¹ See Ran Blake, *Primacy of the Ear* (Lulu.com, 1st ed, 2011).

The Improvisational Codex

The decision to choose the following composers as representative of those compositional techniques best suited for my improvisational codex came from a thorough research of several French, German, British, and American composers' piano repertoires, their contributions to early 20th-century modernism, and whether their work influenced others succeeding the turn of the 20th century. I imposed a general timeline of 1900 to 1944, after the disconnect with Wagnerian Romanticism and the beginnings of Debussyan Impressionism at the turn of the century, up until the publication of Messiaen's two masterpieces in 1944—the sweeping metaphysical solo piano cycle *Vingt Regards sur L'enfant-Jésus* and the exemplary treatise *The Technique of My Musical Language*. My original list included Schoenberg, Hindemith, Ravel, Sorabji, Barber, Ives, Cowell, and Messiaen; around the summer of 2022 I eventually narrowed it down to Claude Debussy, Maurice Ravel, and Charles Ives. These composers convinced me that not only did their compositional output for piano (including piano sonatas, piano concertos, and piano chamber music) excel those of their contemporaries, but their innovations still exist today as exemplary icons of 20th-century compositional practice.

The following list categorizes each “-ism” and “-ality” with a companion musicological source and historical background. Not all of the techniques listed here were used in the *Sonata for Improvising Piano*, No. 1, but substantial opportunity exists to document the entire collection in a forthcoming treatise, not unlike those previously written by notable 19th-century luminaries Czerny²² and Kalkbrenner.²³

Index of Compositional Techniques from Ravel, Debussy, and Ives

i. Modal and Modernistic Techniques of Debussy and Ravel

Both Claude Debussy and Maurice Ravel extended upon the use of modality with chromaticism and nonfunctional diatonicism as part of the continuation of musical modernism at the turn of the 20th-century.²⁴ However idiosyncratic these two composers may have been, and however inappropriate that their work was labeled “impressionistic” within certain musicological contexts, their combined mastery of modal

²² See Czerny 1983.

²³ See Kalkbrenner 1970.

²⁴ For a thorough discussion on Debussy's tonal practice, see Pomeroy 2003, 156–161.

technique, baroque and 19th-century classical forms (e.g., sonata-allegro), ostinato, parallelism, and polychords comprising extensions of harmonic function via the use of the 9th, 11th, and 13th intervals was among the chief pioneering achievements in 20th-century compositional design, with a bona fide French influence, and therefore highly adaptable to my improvisational schemata.

According to Roy Howat, the octatonic scale was adopted by Ravel as a revolutionary modal enhancer in *Jeux d'eau*²⁵ well before Stravinsky's popular use of it in his *Firebird* and *Petrushka* ballets (Howat 2009, 11). Ravel largely abandoned the whole tone scale after his early "*Scheherazade* overture...opting for the octatonic mode of alternating semitones and tones" (10). Most likely influenced by Rimsky-Korsakov's use of the octatonic scale, Ravel was able to write lush sonorities of the octatonic within subtly masked diatonic foregrounds, exploiting the triadic and non-diatonic functions of the octatonic in a myriad of possibilities, most notably in the virtuosic symbolist-influenced *Gaspard de la nuit*. Howat points out an example of Ravel's tectonic use of the octatonic scale in the third movement, *Scarbo*, by clarifying that "there is an obvious, structurally relevant octatonically descending bass line into the final climax" (11). This multiplicity of modal adaptation is part of a general modal technique of impressionism that Howat describes:

Modes can work in several dimensions at once: as melody, as modal harmony, or stretched out over a slower bass line with varying harmonies above. (Howat, 11)

In the first movement of my Sonata, *Le Chatoyant* (The Shimmering) (Fig. 1),²⁶ I have arranged an impressionistic tableaux of textural instructions regarding the use of several modes in different combinations with thematic material.

Contrastingly, Debussy's modal technique is more tonally prioritized, with a preference for the use of the Lydian-mixolydian with a raised 4th and flattened 7th, and the whole-tone scale. Defined as "modal refraction on nested levels" (Howat 2009, 6), Debussy's lack of direct between keys is replaced by the insertion of chromatic behavior between

²⁵ See Taruskin "Getting Rid of Glue" for a distinctly non-octatonic discussion of Ravel's use of the combined C and F# major triadic polychord in the cadenza of *Jeux d'eau*, especially as a "functional French sixth chord on F#" (5).

²⁶ A filmed live performance of Mvt. 1 by this author is available at <https://youtu.be/feIjm3GnPFg>. Evan Whitfield, "Sonata for Improvising Piano, No. 1 - Mvt. 1, Le Chatoyant (The Shimmering)," *YouTube*, Dec. 26, 2022.

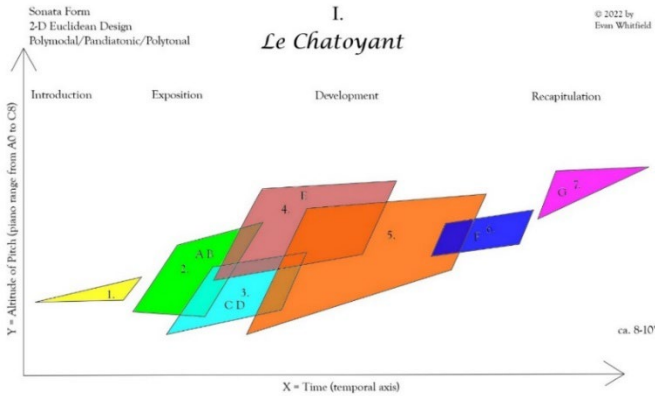


Fig. 1. Graphic score realization of Evan Whitfield's *Sonata for Improvising Piano*, No. 1, Mvt. 1, *Le Chatoyant*.

diatonic planes, juxtaposed within a hierarchy of modal relationships and layering. This combination of “modal variety” and a mixture of “diatonicity and chromaticism” (8) allows for a “masking of diatonic cadences and progressions” (8), and “lets non-cadential modal areas intervene between the essential motions of cadential tonality” (33).

Before 1900 and in the two decades shortly thereafter, a number of important works were written by Debussy, including *Préludes*, books 1 and 2, and *Images* for orchestra,²⁷ from which I adapted the first movement's theme (*Gigues*) for inclusion in the third movement of my *Sonata*, *Les Danses sur la Place* (*Dances in the Square*) (Fig. 2).²⁸ The usefulness in not completely abandoning functional tonality but in allowing it to blend with new modal varieties and compositional directions is an important concept in grounding any model of early 20th-century post-tonal piano improvisation. Posturing a restriction on absolute atonality could be an important factor in allowing for a gravitational anchor on improvisational harmonic freedom and Debussy's work is an excellent example showcasing a balance of nonfunctional diatonicism, modality, and chromaticism. In summarizing Debussy's early oeuvre, Boyd Pomeroy states:

²⁷ See Pomeroy 156.

²⁸ A filmed live performance of Mvt. 3 by this author is available at <https://youtu.be/KZyoYcMQKQ0>. Evan Whitfield, "Sonata for Improvising Piano, No. 1 - Mvt. 3, *Les Danses sur la Place* (The Dances in the Square)," *YouTube*, Dec. 26, 2022.

...Debussy's progressive tonal outlook is clearly evident in his fondness for juxtaposing remotely related chromatic regions with exotic-sounding uses of chromatic modality, and perhaps most of all in a characteristic penchant for certain non-diatonic pitch collections, especially the whole-tone and octatonic scales. (Pomeroy 2003, 156)

The use of parallelism—the sequencing of chains of 7th, 9th, or 11th chords—labelled “chemistry” by Debussy (Howat 2009, 12), also enabled an “active sequence of modal color” (12). According to Kostka and Santa (2018), “parallel 5^{ths} also occur in chordal parallelism, a very important development in 20th-century music” (76). This practice can sometimes verge on redundancy, because “in post-tonal music... composers have been unrestrained in their use of harmonic

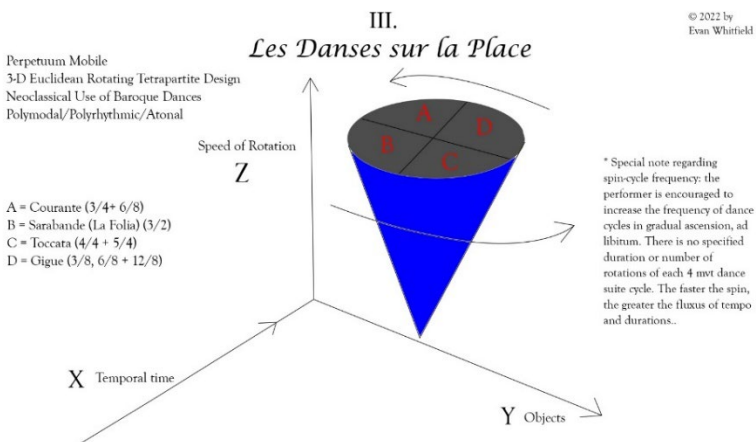


Fig. 2. Graphic score realization of Evan Whitfield's *Sonata for Improvising Piano*, No. 1, Mvt. 3, *Les Danses sur la Place*.

parallelism...” (76). Some contemporary composers of post-tonal music (e.g., Bartok) show evidence of an extension of parallelism called *planing*, a term that describes vast registral shifting of extended seventh chords moving in diagonal vertices across the keyboard.²⁹ Similar registral shifting can occur in orchestral contexts. Alternative associations include “‘organum’ for harmonic parallelism in post-tonal

²⁹ See Kostka and Santa 2018, 76–78.

music, especially when it involves root-position triads” (83). Ravel was also keen to use parallel chords in his piano music, and a device described by G.W. Hopkins as an “ostinato pedaling figure” (Nectoux et al. 1986, 179) supported progressions of 11th chords “which verge on bitonality” (179).

The cloaking of the sonata form by Ravel in his compositions was an extreme example of the new breed of post-tonal composers reworking late 19th-century plasticity; the fact that Ravel was not only able to mask 19th-century tonality but also subsume its predictable forms is a testament to his skill at rejuvenating antique traditions. It is also a tribute to how malleable and reworkable the sonata (or sonata-allegro) form really is. In an insightful analyzation of *Scarbo*, the third movement of Ravel’s *Gaspard de la nuit*, Daphne Leong and David Korevaar expertly dissect Ravel’s thematic layout into an intrepid arrangement of the typical sonata form’s introduction, exposition, development, and recapitulation sections and how each is entwined in a cyclical thematic transformation engineered by Ravel’s precision design.³⁰ In a programmatic context of the dwarf—the principal symbolist-evolved character-motive in question—they show “how this thematic cycle itself recurs, transformed, in the development and in the recapitulation, and how this varied repetition on the expanding levels of figure, formal section, and movement...express the dwarf’s continual motion and changing shapes” (Leong and Korevaar 2011, 129). Utilizing a “model/copy” formula to illustrate Ravel’s ingenuity,

each theme expresses a version of the classical development technique “model-copy (-fragments),” where the “model”...is the first statement of material, the “copy”...its sequential re-statement or restatements, and the “fragments”...where present, shortened versions of sequential restatements. (Leong and Korevaar 2011, 129)

Even more intriguing is that Ravel maintains a structural integrity throughout:

...the apparent *thematic* parallels between introduction-exposition and recapitulation are reinterpreted by the *harmonic* parallels between the two large areas—a masterful reinterpretation

³⁰ See Leong and Korevaar 2011, 126–137. For another exemplary, parallel discussion of *Gaspard de la nuit*’s cyclical thematic structure masking an inviolate sonata form, see Howat 2009, 35–36.

of thematic design by harmonic structure. (Leong and Korevaar 2011, 137)

My research confirming the illusive borrowing of sonata form by Ravel³¹ was one of the most important influences for my decision to use sonata form as a basis for my model, the *Sonata for Improvising Piano*, No. 1.

Equally resonant from my study of Ravel is the fact that “Ravel’s technique relied to an unusual extent on the manipulation of musical objects” (Nectoux et al. 1986, 170–171). In an insightful essay on Ravel’s compositional technique, G.W. Hopkins elaborates on the idea of the ‘musical object,’ which “suggests a musical element considered in its own right as self-sufficient...free from the functional roles expected...”(171). Hopkins continues:

Since the object cannot...participate in ‘subjective’ functions (those normally associated with music exposition and development), its temporal extension must be constituted either of stasis or some form of ‘objective’ (i.e., mechanical, automatic) movement. (171)

Theorist, scholar, and musicologist Deborah Mawer has also determined that the musical object was an integral, perhaps Symbolist-influenced philosophical *raison d’être* of Ravel:

An important part of Ravel’s compositional aesthetic is bound up with objectification, crystallization and detachment, ideas that connect with Symbolist notions of imagery, Cubist notions of spatial and temporal planes and, beyond World War 1, with the basic tenets of neoclassicism. (Mawer 2000, 47)

She defines a musical object as a “fixed, passive entity, as distinct from a motive which engenders organic growth and development” (48). Although I disagree with her classification of a musical object not having motivic and thematic properties, this concept is essential to my model for contemporary classical piano improvisation, because the object can be transferred and envisaged as a graphic item in a score, a text-based musical instruction, or a precomposed musical motive with structural intentions. Reinterpreting Hopkins, Mawer observes:

³¹ For additional comparison studies of Ravel’s innovative and labyrinthine use of sonata form, especially in his String Quartet, Piano Trio, and *Jeux d’eau*, see Taruskin “Getting Rid of Glue” and Heinzelmann, 2000.

A basic premise of Hopkins is then that a musical object is essentially ‘synoptic’—in his use of the term as ‘perceivable from a single standpoint’—and that its main means of extension, or movement, is created through time by simple sustaining, or repetition. It might...still be possible for the temporal dimension to simulate rotation of an object (through inversion, reversion, or exact sequence), as though Ravel and ourselves, as the dual subjects—creator and receiver—are able to view the object from more than one perspective. (Mawer 2000, 49)

Thus, my conceptual use of the *objective* ‘musical object’ is defined as existing outside of a *subjective* tonal foreground and middle ground. The concrete abstraction of the idea of a musical object is relatively comparable with any avant-garde improvisational conception. One could even assimilate associative concepts like ‘blocks of musical space,’ with objects organized within their temporality. This theoretical conception culminated in the graphic score design of the fourth movement of my Sonata, *L’Éclipse qui a Transformé la Montagne en Ombres* (The Eclipse that Transformed the Mountain into Shadows), which is a metaphysical and Zen-inspired essay based on programmatic naturalism (Fig. 3).³²

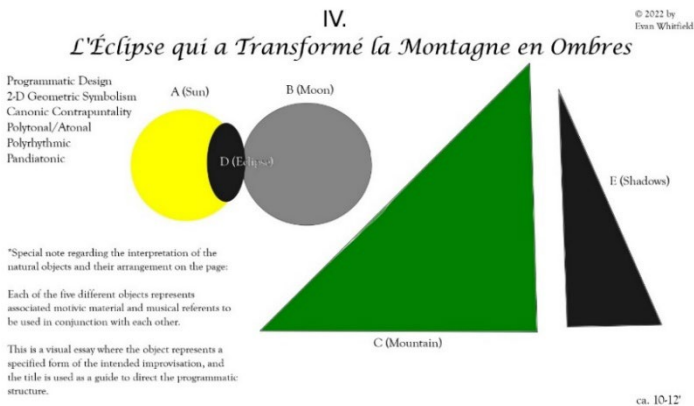


Fig. 3. Graphic score realization of Evan Whitfield’s *Sonata for Improvising Piano*, No. 1, Mvt. 4, *L’Éclipse qui a Transformé la Montagne en Ombres*.

³² A filmed live performance of Mvt. 4 by this author is available at <https://youtu.be/LqcAumnyuYo>. Evan Whitfield, “Sonata for Improvising Piano, No. 1 - Mvt 4, L’Éclipse qui a Transformé la Montagne en Ombres,” *YouTube*, Dec. 26, 2022.

ii. *Polymeter*

The early part of the 20th-century brought about new innovations in style that pushed the boundaries of tonality, chromaticism, and rhythmic displacement: metrical offset and new perceptions in metrical texture were introduced by the works of Debussy, Ravel, Messiaen, and Charles Ives. Polymetricity, or polymeter, is a term that can be applied to describe a phalanx of symmetrical or incongruent compound meters flowing in contrapuntal fashion, either structurally relevant or existing purely for a new form of style. “Metrical dissonance,” a term proposed by Wallace Berry, can be applied to measure the levels of metrical irregularity against symmetrical metrical pacing.³³ Polymeter—with its presumed metrical fluctuations of thematic content—should be structurally anchored within any model of 20th-century contemporary classical improvisation, thereby asserting its role as a functional process, rather than a purely spontaneous and cumulative behavior. Berry offers his structural viewpoint of metric use in a composition:

Except in random situations, changes in meter...are structurally functional. As with any structural element, there is a vast breadth of possibilities of metric stability on one hand (constant, unchanging interval of initiative accentuation at all levels in all textural components) and of instability on the other (total avoidance of like contiguous or concurrent units in the metric structure, continued fluctuations of meter at all levels). Control of meter within such extremes is a fundamental factor in the articulation of musical structure. (Berry 1987, 377)

In an improvisational setting, encouraging structural relativity within the mechanics of post-tonal music may seem daunting. Charles Ives, in his monumental, transcendental stream-of-conscious *Concord Sonata*, leaves open the question concerning metrical organization, offering performers a rare opportunity to recreate the metric foreground themselves by withholding time signatures and bar lines throughout most of the score:

Ives facilitates the unimpeded flow of his musical stream of thought throughout the score of the “Concord” Sonata. This is apparent in his exceedingly spare use of bar lines, which gives much of the score the appearance of a run-on musical sentence.

³³ See Berry 1987, 362.

Similarly, time signatures are indicated only rarely. As a result, any determination of metric organization is almost entirely left up to the performer... (Bruhn 2011, 176)

If a median between metric organization and the freedom of improvisational spontaneous flow can be ascertained, thematic integrity within a framework of structural improvisation could well be established. The improvisational feel of Ives's *Concord Sonata* is an excellent companion reference to my *Sonata for Improvising Piano*, No. 1, because many of the techniques of my proposed codex are equally championed in Ives's grand manifesto for solo piano. In the second movement of my *Sonata*, *Les Pendules* (The Clocks),³⁴ I constructed a flexible format for polymetric fluidity by graphically depicting a large clock I call the "big clock," wherein there are five smaller clocks representing different values of meter and tempo (Fig. 4).

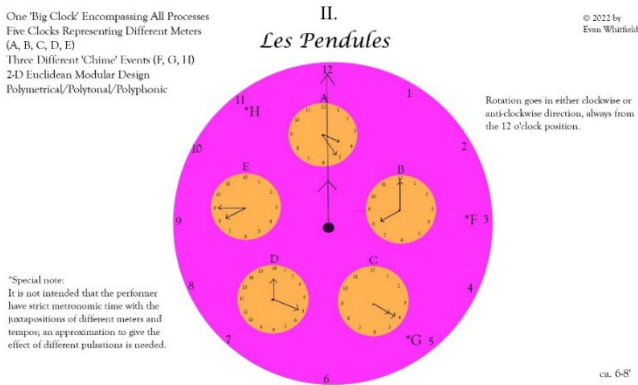


Fig. 4. Graphic score realization of Evan Whitfield's *Sonata for Improvising Piano*, No. 1, Mvt. 2, *Les Pendules*.

Accompanying pages depict the thematic content to be improvised upon, corresponding to a table of each different tempo and meter combination (not shown). I have also given the performer-improviser two choices in the direction of the big clock, either a clockwise or an anti-clockwise rotation. The two rotational axes allow for opposite action-flows of circular-linear time, and the idea is to encourage

³⁴A filmed live performance of Mvt. 2 by this author is available at <https://youtu.be/ptOD1A8VmzU>. Evan Whitfield, "Sonata for Improvising Piano, No. 1 - Mvt. 2, Les Pendules (The Clocks)," *YouTube*, Dec. 26, 2022.

occasional overlap between each pair of differing time signatures and tempos, thus initiating a bimetric compound coagulation, a polymetric effect.

iii. The Innovative Techniques of Charles Ives's Concord Sonata

The inclusion of Charles Ives as an innovator of early 20th-century post-tonal classical musical modernisms should come as no surprise. Not only was Ives a celebrated organist in his home state of Connecticut before and after the turn of the 20th century,³⁵ but he was also a versatile improvising pianist who recorded his own improvisations on themes of his own music.³⁶ Ivesian compositional techniques were the darling of the early American 20th-century in classical music.³⁷ Before most of Europe had absorbed the Schoenbergian effect of dodecaphonic principles, Ives had already established himself as superlative inventor of a wide range of techniques including quotation, polyphonic atonality, cluster chords, the use of overtones, stream-of-conscious form, and polyharmonic dissonance;³⁸ most of these processes were unequalled in the European musical avant-garde of the early 1900s. The *Concord Sonata* (Piano Sonata No. 2), Ives's most famous work for solo piano, is an incredible tour-de-force of compositional virtuosity, consisting of ametrical phrasing with no clear delineations of bar lines, no time signatures, and few instances of key signatures.³⁹ Its immense improvisational quality cannot be doubted; its odyssean transcendental complexity is unrivalled with contemporary composers of Ives's time; and it continues to exist as a uniquely American 20th-century hallmark of Ives's compositional genius.

Christopher Bruhn has written an excellent analysis of the principles and innovations behind Ives's *Concord Sonata*, which led me to acknowledge that Ives's singular idiosyncratic compositional behaviorisms would be a challenging effort to include in my improvisational codex. The highly dissonant harmonic aspects of Ives's work at first seemed unsettling to me, but after comparing the extreme density of some of the *Concord* material to examples from Messiaen, the context soon became clear. Post-tonal, modern improvised piano music would need to include a diverse range of sound possibilities: the intense

³⁵ See Swafford 1988.

³⁶ See Ives 1999.

³⁷ See Swafford 1988.

³⁸ See Bruhn 2011.

³⁹ See Ives *Sonata No. 2*.

harmonic vocabulary combined with the polymetric and polyphonic contrapuntality of the *Concord Sonata* would succeed in offering musical extremities that only a revolutionary improvising pianist around the turn of the century could demand. Bruhn clarifies:

Ives'[s] wide-ranging harmonic excursions are given free play through the absence of key signatures throughout most of the "Concord" Sonata, with accidentals added purely on an as-needed basis. This encourages performers to think openly and flexibly about the harmonic environment of the work from moment to moment...(Bruhn 2011, 177)

Although some pianists may find it daunting to navigate the misty clouds of Ives's compositional fabric, the techniques that Ives uses include:

...fragmentation, polyphonic textures, registral displacement of individual pitches within melodies, the inclusion of wrong notes in tunes that otherwise seem somehow familiar, the harmonic distortion of melodies with dissonant accompaniments, and the addition of overtones—written as tiny noteheads in the score—to decorate melodies with hauntingly resonant, shimmering pings. (Bruhn 2011, 178)

Reharmonizations of popular material—such as marching tunes, quotations from classical composers such as Beethoven, and excerpts from hymns in dissonant polyphonic arrangements—are the distinct sound of Ives's music, as well as the linear development of these motives in broader formal structures, e.g., a theme and variations in the first movement of the *Concord Sonata*, "Emerson." As Bruhn describes, the main theme

...is constantly unfolding in new ways: registral displacement of the melody in the first variation, an accompaniment of fast triplets and dissonant harmonization of the melody in the second, a lush harmonization of the melody in diminution in the third, and so on. (179)

In addition to the complex harmonic displacement of common themes is the fact that Ives used a somewhat loosely defined formal structure—one in which a type of retrograde was implied—coined by J. Peter Burkholder as "cumulative form" (Burkholder 1995, 137): "a thematic, non-repetitive form in which the principal theme is presented,

not at the beginning [of a movement] as in traditional forms, but near the end, and is preceded, not followed, by its development” (qtd in Bruhn 181).

An important yet highly abstract phenomenon of Ives’s music, “sonic exuviation,” was first conceived by Nicolas Slonimsky in his musicological tome, *Music Since 1900*,⁴⁰ wherein he describes it as “a cut-off of sonic matter, leaving a soft exposed bodily shape” (qtd. in Bruhn 179). Burkholder also offers an additional observation, describing it as an occurrence when “a noisy climax suddenly cuts off to reveal another plane of sound, softer and more distant, representing something that has been going on all the time unheard” (qtd. in Bruhn 179). This fascinating yet perceived aestheticism of Ives’s futuristic endeavors rivals those composers of the mid-1950s and is a technique that I desire to include—once practiced carefully and internalized—in my improvisational codex.

Burkholder also offers illuminating explanations of Ivesian compositional processes, which he categorizes under the title: “Uses of Existing Music in the Works of Charles Ives” (Burkholder 1994, 854). A brief overview of this table portrays an array of interesting applications from “paraphrasing an existing tune to form a new melody, theme, or motive” to “programmatic quotation” and “collage” (854). The myriad of creative ways that Ives exploits the technique of quotation, including arrangements of popular tunes in polyphonic fashion, is a welcome refreshment to expand upon the available procedures adaptive to a model for 20th-century contemporary classical solo piano improvisation.

From the fall of 2021 to the summer of 2022, I had the wonderful opportunity to engage in creative philosophy with my doctoral supervisors, Douglas Finch and Aleksander Szram, at the Trinity Laban Conservatoire of Music & Dance in Greenwich, UK. They were curious, intelligent, and remarkably lucid with their suggestions and reflections concerning my contemporary classical piano/structural improvisation research thesis. Because of the nature of the research methodology of Practice as Research, a majority of this experiment was documented by me in the form of practice-as-research journal logs. Because this paper would have been significantly lengthened to include an insightful behind-the-scenes clockwork of this practitioner–researcher’s creative methods and procedures, it is important to note that keeping a daily or weekly journal detailing the research progress leads to a surprisingly mystifying degree of tacit knowledge—a feedback loop of beneficial self-analysis and self-reflection, pulling the researcher closer to their

⁴⁰ See Nicolas Slonimsky’s *Music Since 1900*, 4th ed. (New York: Charles Scribner’s Sons, 1971), 1491 (qtd. in Bruhn 2011).

goal. A major portion of my research involves transcribing recorded improvisations and analyzing the results; the effort here is to find and isolate musical phenomenon that could support some of Jeff Pressing's theories regarding cognitive processing in improvisational behavior. Equally relevant is that a large section of Western organ improvisation practice—existing today in some parts of France, Germany, and Northern Europe—needs to be acknowledged and supported by more scholars from the musicological community. Sadly, classical improvisation today remains greatly undervalued and underrepresented as a valid form of musical performance practice in most music education programs at the middle and high school levels and throughout institutions of higher learning in North America. Obviously, more work needs to be done to educate aspiring musicians and music educators on the benefits of teaching improvisation in the classroom. I hope the reader has gained an appreciation for contemporary classical solo piano improvisation as a possible future performance style and will help support improvisational research and practice.

References

Azzara, Christopher D. "Improvisation." In *The New Handbook of Research on Music Teaching and Learning*, edited by Richard Colwell and Carol Richardson. Oxford University Press, 2002, pp. 171–187.

Bailey, Derek. *Improvisation: Its Nature and Practice in Music*. Da Capo Press, 1993.

Bhagwati, Sandeep. "Notational perspective and improvisation." In *Sound and Score: Essays on Sound, Score and Notation*, edited by Paulo de Assis, William Brooks, and Kathleen Coessens, Leuven University Press, 2013, pp. 165–177.

Berry, Wallace. *Structural Functions in Music*. Dover, 1987.

Blake, Ran. *Primacy of the Ear*. Lulu.com, 2011.

Brindle, Reginald Smith. *The New Music: The Avant-Garde Since 1945*, 2nd ed., Oxford University Press, 1987.

Bruhn, Christopher. "The transitive multiverse of Charles Ives's 'Concord' Sonata." *The Journal of Musicology*, vol. 28, no. 2, 2011, pp. 166–94, <https://doi.org/10.1525/jm.2011.28.2.166>.

Burkholder, J. Peter. *All Made of Tunes: Charles Ives and the Uses of Musical Borrowing*. Yale University Press, 1995.

—. “The uses of existing music: musical borrowing as a field.” *Notes*, vol. 50, no. 3, 1994, pp. 851–70. <https://doi.org/10.2307/898531>.

Czerny, Carl. *A Systematic Introduction to Improvisation on the Pianoforte, Op. 200*. Translated and edited by Alice L. Mitchell. Longman, 1983.

Dale, Michael. *What is Comprovisation?* 2008. Master’s dissertation, Mills College.

Després, Jean Phillip, Pamela Burnard, Francis Dubé, and Sophie Stévançe. “Expert Western classical music improvisers’ strategies.” *Journal of Research in Music Education*, vol. 1, no. 24, 2017, pp. 139-162.

Dolan, David. “Back to the future: towards the revival of extemporisation in classical music performance.” In *The Reflective Conservatoire: Studies in Music Education*, edited by George Odam & Nicholas Bannan, Ashgate Publishing, 2005, pp. 97-132.

Edin, Martin. *Piano Improvisation according to Czerny and Liszt: 19th Century Preluding and Piano Improvisation Practice – Analysis and Examples*. 2008. Masters dissertation, Örebro University.

Goldstein, Malcolm. *Sounding the Full Circle: Concerning Music Improvisation and Other Related Matters*. Self-published, 1988.

Goertzen, Valerie Woodring. “By way of introduction: preluding by 18th- and early 19th-century pianists.” *The Journal of Musicology*, vol. 14, no. 3, 1996, pp. 299–337.

Gooley, Dana. *Fantasies of Improvisation: Free Playing in 19th-Century Music*. Oxford University Press, 2018.

Hamilton, Kenneth. *After the Golden Age: Romantic Pianism and Modern Performance*. Oxford University Press, 2008.

Heinzelmann, Sigrun B. "Playing with models: sonata form in Ravel's String Quartet and Piano Trio." In *Unmasking Ravel: New Perspectives on the Music*, edited by Peter Kaminsky, vol. 84, Boydell & Brewer, 2011, pp. 143–79.

Howat, Roy. *The Art of French Piano Music: Debussy, Ravel, Fauré, Chabrier*. Yale University Press, 2009.

Ives, Charles, perf. *Ives Plays Ives*. By Charles Ives, Comp. Composers Recordings Inc., 1999. CD

Ives, Charles. *Sonata No. 2: Concord, Mass 1840-60*, 2nd Edition. Associated Music Publishers Inc, 1947

Kalkbrenner, Friedrich Wilhelm. *Traité D'harmonie du Pianiste, Op. 185*. Breitkopf & Hartel, 1849/Heuwekemeyer, 1970.

Kostka, Stefan and Matthew Santa. *Materials and Techniques of Post-Tonal Music*, 5th ed., Routledge, 2018.

Lewis, George E. "Improvised music after 1950: Afrological and Eurological perspectives." *Black Music Research Journal*, vol. 22, 2002, pp. 215–246.

Leong, Daphne and David Korevaar. "Repetition as musical motion in Ravel's piano writing." In *Unmasking Ravel: New Perspectives on the Music*, edited by Peter Kaminsky, 2011, pp. 111-143.

Mawer, Deborah. "Musical objects and machines." In *The Cambridge Companion to Ravel*, edited by Deborah Mawer, Cambridge University Press, 2000, pp. 47–70.

Neeman, Edward. *Free Improvisation as a Performance Technique: Group Creativity and Interpreting Graphic Scores*. 2014. DMA dissertation, The Julliard School.

Nectoux, Jean Michel, Roger Nichols, Patrick Govers, Gary Hopkins, and Paul Griffiths. *The New Grove 20th-Century French Masters: Fauré, Debussy, Satie, Ravel, Poulenc, Messiaen, Boulez*. Macmillan, 1986.

Nelson, Robin. "Practice-as-research and the problem of knowledge." *Performance Research*, vol. 11, no. 4, 2006, pp. 105–116. <http://doi.org/10.1080/13528160701363556>.

Pomeroy, Boyd. "Debussy's tonality: a formal perspective." In *The Cambridge Companion to Debussy*, edited by Simon Trezise, Cambridge University Press, 2003, pp. 153–178. <http://doi.org/10.1017/CCOL9780521652438.011>.

Persichetti, Vincent. *20th-Century Harmony: Creative Aspects and Practice*. Faber, 1978.

Phillip, Robert. *Performing Music in the Age of Recording*. Yale University Press, 2004.

Pressing, Jeff. "Cognitive processes in improvisation." *Advances in Psychology: Cognitive Processes in the Perception of Art*, vol. 19, 1984, pp. 345–363.

—. "Improvisation: Methods and Models." In *Generative Processes in Music: The Psychology of Performance, Improvisation and Composition*, edited by John Sloboda, Oxford University Press, 1988, pp. 129–178.

Strauss, Joseph N. *Introduction to Post-Tonal Theory*, 2nd ed., Prentice Hall, 2000.

Swafford, Jan. "Ives the Man: His Life." Charles Ives Society, 1998, Accessed December 21, 2022, at www.charlesives.org/ives-man-his-life.

Tandberg, Svein Erik. *Imagination, Form, Movement and Sound: Studies in Musical Improvisation*. 2008. PhD dissertation, University of Gothenburg.

—. "Chapter 2 Getting rid of glue." In. Oxford University Press, 2010. <https://www.oxfordwesternmusic.com/view/Volume4/actrade-9780195384840-div1-002009.xml>.

Thomas, Phillip. "Comprovisation CD." Liner notes. *Comprovisation. Bruce's Fingers*, 2007. CD.

Whitfield, Evan. *Sonata for Improvising Piano, No. 1*. 2022. LinkedIn, https://www.linkedin.com/posts/evanwhitfield_sonata-for-improvising-piano-no-1-2022-activity-7022654537064742912-8H1Z?utm_source=share&utm_medium=member_desktop.

- . “Sonata for Improvising Piano, No. 1, Mvt. 1, Le Chatoyant (The Shimmering).” YouTube, 26 Dec. 2022. <https://youtu.be/feIjm3GnPFg>.
- . “Sonata for Improvising Piano, No. 1, Mvt. 2, Les Pendules (The Clocks).” YouTube, 26 Dec. 2022. <https://youtu.be/ptOD1A8VmzU>.
- . “Sonata for Improvising Piano, No. 1, Mvt. 3, Les Danses sur la Place (The Dances in the Square).” YouTube, 26 Dec. 2022. <https://youtu.be/KZyoYcMQKQ0>.
- . “Sonata for Improvising Piano, No. 1, Mvt 4, L'Éclipse qui a Transformé la Montagne en Ombres.” YouTube, 26 Dec. 2022. <https://youtu.be/LqcAummYuYo>.

Ditch the Stress: How Mindfulness Activities Affected Perceived Stress, Mood, and Well-being in University Students During the COVID-19 Pandemic

Jayden D. Peacock, Dylan T. Gardner, Korina K. Ziegler, Colton G. Davis, and Helen C. Boswell-Taylor
Southern Utah University

Abstract

Mental wellness is a large concern on college campuses, especially since the outbreak of COVID-19 and its resulting negative impact on student social and mental health. We tested the effectiveness of mindfulness activities on perceived stress levels, mood, and well-being of university students. We organized a campus event for students at Southern Utah University involving the opportunity to participate in four different mindfulness activities. Before participating, students completed a self-reported intake survey, and afterwards, they completed a post-activity survey. After one week of practicing a mindfulness activity on their own time, students completed a post-week survey. Two mindfulness activities were associated with an immediate reduction of perceived stress, increase in mood, and increase in well-being: coloring pages and progressive muscle relaxation. Longer-term reduction of perceived

stress and increase in well-being also occurred in students who completed coloring pages. In addition, longer-term reduction of perceived stress occurred in students who completed progressive muscle relaxation. Mood did not significantly change from intake after completing any of the activities for one week. We were able to demonstrate specific accessible, affordable mindfulness activities that are likely to help students with stress, mood, and overall well-being. We recommend that these activity types be employed on college campuses on a regular basis.

Introduction

At the onset of the COVID-19 pandemic, university campuses undertook a variety of safety measures that limited social interaction, including remote learning, social distancing, and restrictions on social activities. These measures had negative effects on social and emotional development for students; as a result, university students experienced increased stress and a sharp decline in mood and overall wellness during the pandemic (Copeland et al. 2021), with depression, anxiety, and suicidal ideation also becoming an increasing concern (Wang et al. 2020). The college lifestyle presents many difficulties for students, including financial responsibilities, living away from home and support systems, peer image perception, exposure to new cultures, performance pressure, competition for academic standing, and fear of failure (Rai et al. 2021).

As students pursue their education, they are also faced with uncertainty about how to deal with basic needs that contribute to their physical and mental well-being (Broton et al. 2022). It is thus evident that the emergence of mental health issues frequently occurs during this vulnerable period of social development for college students (Liu et al. 2019). Specific social groups on college campuses have been found to improve mental status (Grace et al. 2022), yet access to such groups during public health quarantines inhibits such participation. Because of the effects of societal stigmas surrounding mental illness (Feeg et al. 2014) and the social confinement of students during the pandemic, our study aimed to test simple and no- or low-cost activities that could improve university students' mental health.

Wellness may be defined based on eight dimensions: physical (e.g., exercise, diet, and sleep), spiritual (e.g., purpose and meaning in life), social (e.g., connections and support systems), intellectual (e.g., problem solving and gaining knowledge), emotional/mental (e.g., relationships and coping strategies), occupational (e.g., work satisfaction),

environmental (e.g., pleasant and supportive surroundings), and financial (e.g., secure monetary situation) (Swarbrick 2006). Together, these aspects of health form the overall well-being of an individual. In this study, we tested the effectiveness of activities that focused on four dimensions of wellness: emotional, physical, social, and spiritual.

Methods

We organized and hosted a free student campus activity at Southern Utah University (SUU) in Cedar City, Utah, in March 2022. The activity was scheduled for two hours during the week in a student-focused area on campus (Student Center) and was a drop-in event, where students could come and go as they wished. At the time of this activity, SUU had lifted all prior social distancing requirements, gathering restrictions, and mask requirements due to the COVID pandemic. Following then-current university requirements for student activities, we conducted a symptom check upon participant entry and provided hand sanitizer; all participants were negative for symptoms. We also asked participants to complete an intake (IN) survey (see Supplementary Material) in which we gathered demographic data and information about regular activities that may impact health and wellness. These included time spent on phone, amount of sleep, number of full meals eaten every day, amount of exercise, and participation in extracurricular activities. At this time, we also asked participants to provide a self-assessment on current stress levels and mood.

During the event, participants were given the option to complete four activities, after which they completed a post-activity (PA) survey (see Supplementary Material) to self-assess stress level, mood, and well-being. These activities are described below:

- *Coloring pages (emotional wellness)*: Participants were given coloring pages with positive messages and markers to color.
- *Progressive muscle relaxation (physical wellness)*: Participants were led in a short mindfulness activity that incorporated progressive muscle relaxation.
- *Pay a compliment (social wellness)*: Participants were instructed to pay an intentional compliment to three people that they did not know prior to the event.
- *Positive reflection with gratitude (spiritual wellness)*: Participants were instructed to reflect on experiences from the past week that made them feel grateful.

Participants were given written instructions for the activity that they completed with an invitation to complete it daily throughout the

subsequent week. After one week, participants were contacted to complete a post-activity survey (see Supplementary Material) to assess stress levels and moods. For measurements of well-being, we incorporated into all three surveys the six questions from the Short Depression-Happiness Scale (SDHS; Joseph et al. 2004) and generated a composite well-being score for each participant based on responses. We also asked participants to report the number of days they had practiced the activity and to rate their level of enjoyment of the activity.

We analyzed our data using Wizard: Statistics & Data Analysis Software for Mac. This study was approved as exempt by the Southern Utah University Institutional Review Board (IRB #12-022022d). All participant identities remained confidential, and we coded responses with initials and birthdates to complete repeated measures analyses. All participants were provided with a list of mental health resources in case counseling or other interventions were needed.

Results

Intake Data

A total of 207 students completed the IN survey at the event. To allow for informed consent, students could only participate in the study if they were at least 18 years old; the average age of our participants was 20 years old. Among the participants who participated, 61.6% were female, 37.5% were male, and 0.9% identified as non-binary.

We gathered information about the frequency of extracurricular activities, exercise habits, smartphone use habits, regularity of eating full meals, and sleep habits. Students most often typically participated in extracurricular activities for 3-5 hours per week (Fig. 1a), exercised 3-5 times per week (Fig. 1b), spent 3-4 hours daily on their phones (Fig. 1c), obtained 7-9 hours of sleep a night (Fig. 1d), and ate 2 full meals per day (Fig. 1e).

Prior to beginning any activities, we asked participants to assess their current level of stress and average level of stress during the current semester on a scale of 1-5 (1=low/no stress; 5=high/extreme stress). Reported semester-long stress scores ranged from 1 to 5, with a mean \pm SD of 3.72 ± 0.13 , and reported current participant stress scores ranged from 1 to 5, with a mean \pm SD of 3.19 ± 0.16 (Fig. 1f); the difference between the semester-long and current stress levels was statistically significant (Wilcoxon signed-rank: $z=5.91$, $p < 0.001$). Perceived semester-long stress was not significantly associated with time spent on

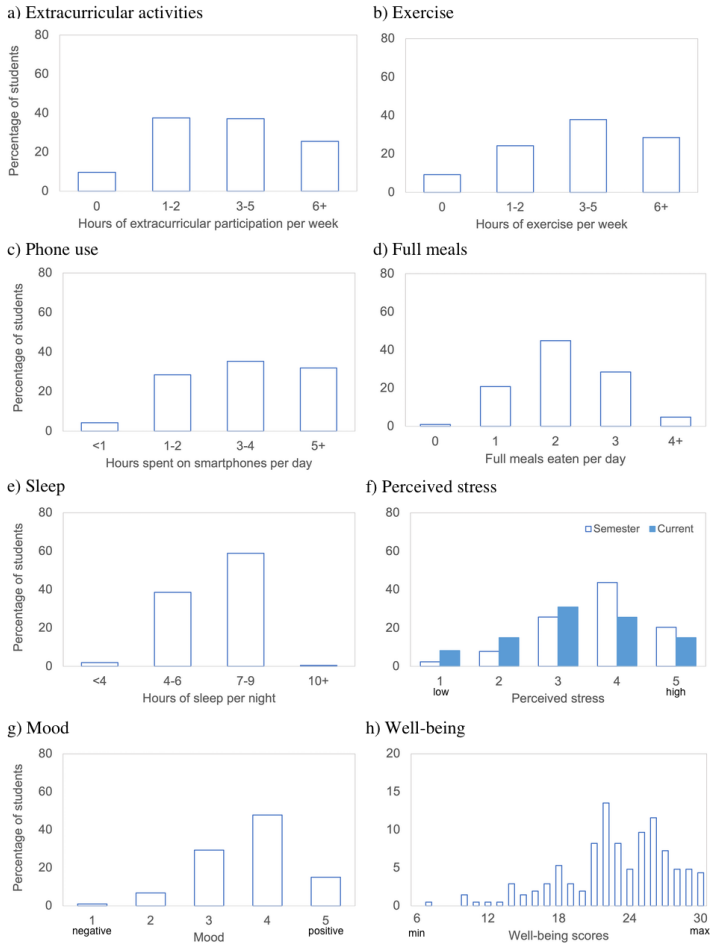


Figure 1. Distributions of student habits, perceived stress, mood, and well-being reported by participants at time of the intake survey. Participants reported their typical (a) weekly hours of participation in extracurricular activities, (b) weekly hours of exercise, (c) daily hours of smartphone use, (d) daily number of full meals, and (e) hours of sleep per night. Participants also reported (f) perceived stress levels for the semester (open bars) and at the time of intake (solid bars) and (g) mood. (h) They were rated for overall well-being using the SDHS method (Joseph et al. 2004). Stress levels are on a 1-5 scale, with 1 being low/no stress and 5 being high/extreme stress (semester mean \pm SD: 3.72 ± 0.13 ; current mean \pm SD: 3.19 ± 0.16), mood is on a 1-5 scale with, 1 being extremely negative and 5 being extremely positive mood (mean \pm SD: 3.69 ± 0.12). Composite well-being scores are on a 6-30 scale, with 6 being low and 30 being high well-being (mean \pm SD: 22.9 ± 0.63).

smartphones (Kruskal-Wallis: $\chi^2=6.462$, $p=0.091$), frequency of exercise (Kruskal-Wallis: $\chi^2=2.477$, $p=0.479$), or frequency of participation in extracurricular activities (Kruskal-Wallis: $\chi^2=2.471$, $p=0.481$). Perceived stress was significantly higher in participants who received an average of 4-6 hours of sleep per night when compared with those who had 7-9 hours of sleep (Mann-Whitney: $z=2.546$, $p=0.011$). It was also significantly higher in participants who reported that they, on average, tend not to eat full meals during the day when compared with those who do (Pearson correlation: $r=-0.151$, $p=0.03$).

We also asked participants to assess their current mood on a scale of 1-5 (1=extremely negative mood; 5=extremely positive mood). The reported mood scores of participants ranged from 1 to 5, with a mean \pm SD of 3.69 ± 0.12 (Fig. 1g). Time spent on smartphones was significantly associated with mood (Kruskal-Wallis: $\chi^2=8.46$, $p=0.037$), with excessive phone use (≥ 4 hours a day) relating to worse moods than individuals who spent < 4 hours on smartphones (post-hoc Mann-Whitney: $z=2.494$, $p=0.013$). Mood was not associated with the frequency of exercise (Kruskal-Wallis: $\chi^2=3.993$, $p=0.262$) but significantly differed with frequency of participation in extracurricular activities (Kruskal-Wallis: $\chi^2=9.009$, $p=0.029$); participants who spent 3-5 hours a week engaging in extracurricular activities reported a more positive mood than those who spent 1-2 hours (post-hoc Mann-Whitney: $z=2.78$, $p=0.005$) or zero hours (post-hoc Mann-Whitney: $z=2.621$, $p=0.009$) engaging in extracurricular activities. Perceived mood was not associated with the total number of hours of sleep (Mann-Whitney: $z=0.998$, $p=0.318$), but it was positively correlated with the number of full meals eaten per day (Pearson correlation: $r=0.171$, $p=0.015$).

We estimated participant well-being using the six questions from the SDHS (Joseph et al. 2004) rated on a scale of 1 to 5 (1=lower well-being; 5=higher well-being), with hypothetical composite scores ranging from a minimum of 6 to a maximum of 30. Participant well-being scores ranged from 7 to 30, with a mean \pm SD of 22.9 ± 0.63 (Fig. 1h). Well-being was significantly lower with excessive phone use (4 or more hours per day) (Kruskal-Wallis: $\chi^2=18.716$, $p < 0.001$) when compared with phone use of 1-2 hours per day (post-hoc Mann-Whitney: $z=3.209$, $p=0.001$) or < 1 hour per day (post-hoc Mann-Whitney: $z=3.117$, $p=0.001$). Well-being was significantly associated with frequency of exercise (Kruskal-Wallis: $\chi^2=10.199$, $p=0.017$), with significantly lower well-being in participants who do not exercise when compared with those who exercise 3-5 times per week (post-hoc Mann-Whitney: $z=1.567$, $p=0.01$) or ≥ 6 hours per week (post-hoc Mann-Whitney: $z=3.042$, $p=0.002$). Well-being was not significantly associated with participation in extracurricular activities (Kruskal-Wallis: $\chi^2=6.824$,

$p=0.078$). Participants who received 7-9 hours of sleep per night had higher well-being scores compared with individuals who receive 4-6 hours of sleep per night (Mann-Whitney: $z=2.172$, $p=0.03$). Well-being was positively correlated with the number of full meals eaten per day (Pearson correlation: $r=0.275$, $p < 0.001$).

Intake Vs. Post-activity Comparisons

Immediately after the wellness activity, participants were invited to evaluate their stress, mood, and SDHS scores. The number of participants who completed PA surveys for our four activities was as follows: coloring pages ($N=51$), progressive muscle relaxation ($N=40$), pay a compliment ($N=14$), and positive reflection with gratitude ($N=13$). The overall response rate (% of IN that completed PA for these four activities) was 57%, with 50% of PA participants being male (75.6% response rate), 49.2% female (45.3% response rate), and 0.8% identifying as nonbinary (100% response rate). We compared individual responses at IN with their responses immediately after completing an activity (PA) using repeated measures analyses (Wilcoxon signed rank).

In comparison with perceived stress levels at IN, PA perceived stress levels of participants significantly decreased after completing coloring pages ($W=305$, $p=0.021$; Fig. 2a, bottom line), progressive muscle relaxation ($W=353$, $p < 0.01$; Fig. 2b, bottom line), and pay a compliment ($W=50$, $p=0.024$; Fig. 2c, bottom line) activities. There was no significant difference between IN and PA perceived stress levels after completing the positive reflection with gratitude activity ($W=10$, $p=0.70$; Fig. 2d, bottom line).

Participant mood was also immediately affected by wellness activities. PA mood significantly increased from IN mood after participants completed coloring pages ($W=282$, $p < 0.001$; Fig. 3a) and progressive muscle relaxation ($W=138$, $p < 0.01$; Fig. 3b) activities. There was no significant difference between IN and PA moods after the pay a compliment ($W=22$, $p=0.078$; Fig. 3c) and positive reflection with gratitude ($W=4$, $p=0.688$; Fig. 3d) activities.

Well-being also showed some effect from certain activities. Well-being scores significantly increased from IN to PA for coloring pages ($W=144$, $p=0.006$) and progressive muscle relaxation ($W=175$, $p=0.003$). Well-being scores did not significantly differ after completion of pay a compliment ($W=10$, $p=0.47$) or positive reflection with gratitude ($W=9$, $p=0.312$) activities (Table 1, middle column).

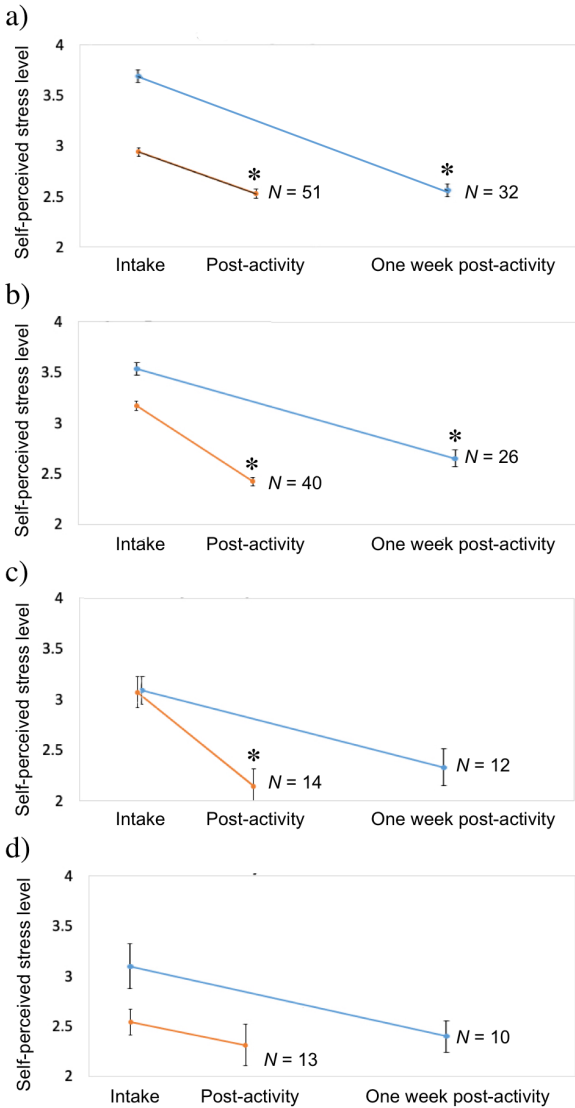


Figure 2. Changes in mean perceived stress levels (\pm S.E.) reported by participants at the time of the intake survey (IN), immediately post-activity (PA), and one week post-activity (PW) for (a) coloring pages, (b) progressive muscle relaxation, (c) pay a compliment, and (d) positive reflection with gratitude. Stress levels are on a 1-5 scale with 1 being low/no stress and 5 being high/extreme stress. Bottom line: changes from IN to PA, top line: changes from IN to PW. *Significant difference compared with IN ($p < 0.05$).

Table 1: Average well-being scores from participants completing surveys

Activity	Mean Well-being Scores (\pm SD) [†]		
	Intake (IN)	Post-Activity (PA)	Post-Week (PW)
Coloring pages	23.71 \pm 1.53	26.09* \pm 1.49	25.92* \pm 1.16
Progressive muscle relaxation	22.93 \pm 2.20	24.32* \pm 1.75	23.44 \pm 2.06
Pay a compliment	24.37 \pm 2.40	26.58 \pm 1.61	26.47 \pm 2.17
Positive reflection	23.78 \pm 3.82	27.33 \pm 2.27	26.7 \pm 2.13

Lowest well-being score=6; highest well-being score=30.

*: significant difference compared to IN ($p < 0.01$).

Intake Vs. Post-week Comparisons

After one week of daily participation in wellness activities, we reevaluated participants on stress, mood, and SDHS scores. The number of participants who continued to complete the activities during the week (PW) following the event was as follows: coloring pages ($N=32$), progressive muscle relaxation ($N=26$), pay a compliment ($N=12$), and positive reflection with gratitude ($N=10$). The overall response rate (% of IN that completed PW for these four activities) was 31.9%, with 50% of PW participants being male (43.6% response rate), 48.5% female (25.8% response rate), and 1.5% identifying as nonbinary (100% response rate). This represents a similar percentage of students by gender who completed PA surveys.

For stress levels, participants who completed activities during the week following the event reported lower perceived stress levels than at IN for the coloring pages (Wilcoxon signed-rank: $W=276$, $p < 0.001$; Fig. 2a, top line) and progressive muscle relaxation (Wilcoxon signed-rank: $W=168$, $p=0.002$; Fig. 2b, top line) activities. There was no significant difference between perceived stress levels at IN versus stress levels at PW for pay a compliment (Wilcoxon signed-rank: $W=24$, $p=0.165$; Fig. 2c, top line) and positive reflection with gratitude (Wilcoxon signed-rank: $W=27$, $p=0.129$; Fig. 2d, top line) activities.

The mood of participants did not differ between IN and PW for any of the activities: coloring pages (Wilcoxon signed-rank: $W=40$, $p=0.323$; Fig. 3a), progressive muscle relaxation (Wilcoxon signed-rank: $W=11$, $p=0.829$; Fig. 3b), pay a compliment (Wilcoxon signed-rank: $W=9$, $p=0.312$; Fig. 3c), and positive reflection with gratitude (Wilcoxon signed-rank: $W=2$, $p=0.75$; Fig. 3d).

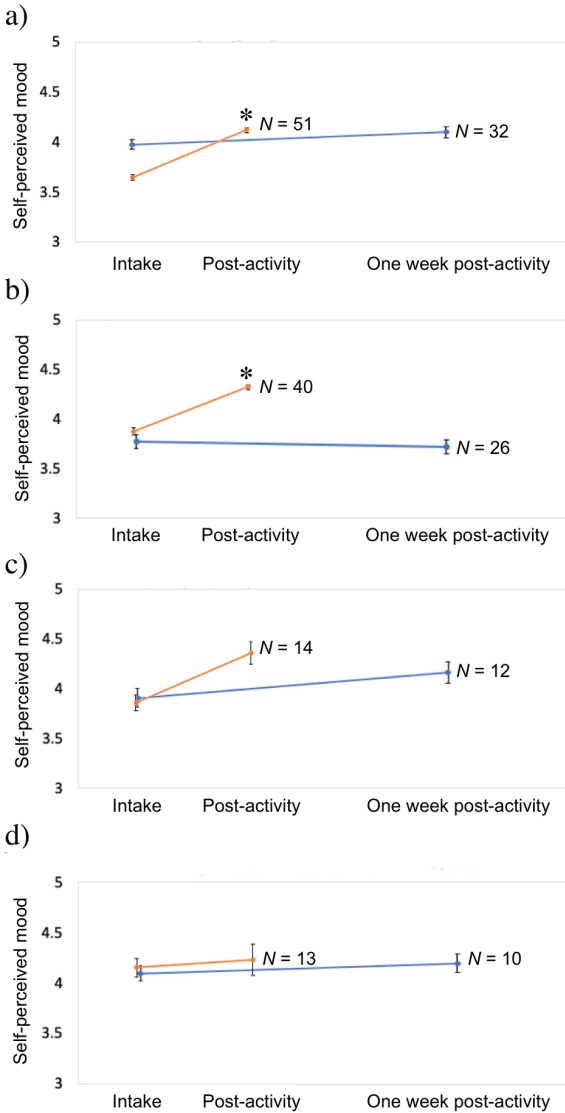


Figure 3. Changes in mood (\pm SE) of participants at the time of the intake survey (IN), immediately post-activity (PA), and one week post-activity (PW) for (a) coloring pages, (b) progressive muscle relaxation, (c) pay a compliment, and (d) positive reflection with gratitude. Mood levels are on a 1-5 scale, with 1 being extremely negative and 5 being extremely positive mood. Top line: changes from IN to PA, bottom line: changes from IN to PW. *Significant difference compared with IN ($p < 0.01$).

Well-being scores significantly increased from IN to PW with the coloring pages activity (Wilcoxon signed-rank: $W=275$, $p=0.002$). Well-being scores did not differ significantly from IN after completing progressive muscle relaxation (Wilcoxon signed-rank: $W=95$, $p=0.103$), pay a compliment (Wilcoxon signed-rank: $W=29$, $p=0.098$), or positive reflection with gratitude (Wilcoxon signed-rank: $W=15$, $p=0.062$) activities during the week following the event (Table 1, right column).

Enjoyment of Post-week Activities

A total of 80 participants followed through and practiced one of the four activities during the week following the event. This represents 66.7% of participants who completed the four activities at the event. We asked participants to score their level of enjoyment of their activity at the end of the week on a scale of 1-5 (1=low enjoyment; 5=high enjoyment). On average, participants' enjoyment of their activity was high, with enjoyment ranging from 1 to 5 with a mean \pm SD of 4.27 ± 0.18 . Enjoyment of the activity was significantly related to how often participants completed their activity during the week (Kruskal-Wallis: $\chi^2=16.017$, $p=0.001$), with lower enjoyment occurring when the activity was completed only 1-2 times compared with when the activity was completed 3-4 times (post-hoc Mann-Whitney $U=155.5$, $p=0.004$), 5-6 times (post-hoc Mann-Whitney $U=103$, $p=0.036$), or every day of the week (post-hoc Mann-Whitney $U=150$, $p=0.001$) (Fig. 4).

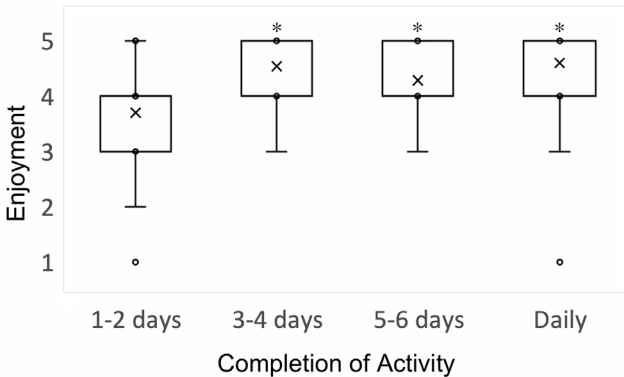


Figure 4. Boxplot showing average participant enjoyment after one week post-activity participation given the number of times participants completed the activity. Enjoyment levels are on a 1-5 scale, with 1 being low enjoyment and 5 being high enjoyment. *Significant difference in categories compared with when activity was completed 1-2 days ($p < 0.05$).

Discussion

In this study, we succeeded in facilitating an activity that showed university students how to carry out mindfulness activities. Two activities in particular, coloring pages and progressive muscle relaxation, were associated with possible immediate benefits to students in all three wellness variables (perceived stress, mood, and well-being) and with longer-term benefits to stress reduction specifically. Additionally, the coloring pages activity was associated with longer-term benefits to well-being. The relative enjoyment that students experienced with the activity was also related to their likelihood of following through with the activity for a longer period.

Coloring activities have been shown to help focus one's mind on a task, which allows for more positive thinking (Simmons 2016, Xi et al. 2022). Coloring as a supplement to conventional drug therapy has also been shown to reduce depression and negative emotions; its potential effectiveness in anxiety reduction may also rival more conventional therapies (Samuel et al. 2022). Online coloring games also yielded results similar to those obtained from physical coloring in aiding mental health, especially in times of isolation, such as during the COVID-19 pandemic (Xi et al. 2022). Immediate improvements in perceived stress, mood, and well-being were also associated with our activity that instructed students to progressively relax muscles, with longer-term improvements in stress reduction after a week of practice. Progressive muscle relaxation techniques have been shown to promote both psychological and physiological relaxation and increase one's sense of overall well-being (Toussaint et al. 2021). Our findings are consistent with the outcomes of these studies, as these psychological benefits were also reported by students at SUU.

In our study, we also observed an immediate, short-term reduction in perceived stress after students paid a compliment to a stranger. Although it may be a challenge for individuals with more introverted personalities, individuals who were initially hesitant to give a compliment felt a boost in their mood after doing so (Boothby & Bohns 2021). Paying forward compliments not only has the potential to benefit the individual delivering the compliment but may also benefit the wellness of the recipient of the compliment. Although we did not see any significant differences in stress, mood, or well-being (either short- or long-term) from the positive reflection activity, self-reflection on daily stressors may still be an effective way of developing coping strategies in the face of adversity (Falon et al. 2021). Intentional gratitude may also improve mental health and encourage positivity (Adair et al. 2020), even following a global pandemic (Kumar et al. 2022).

One limitation of our study was that students who voluntarily participated in our event may not have represented a random sampling of the student population. More females than males participated in the IN survey, but males were then more likely to continue and complete the PA surveys. Approximately equal proportions of the genders who completed PA surveys committed to completing a wellness activity during the following week. Although our measures of mental wellness (perceived stress, mood, and well-being) were highly variable, the intake survey showed that, on average, students perceived their stress levels to be moderately high during the semester but significantly lower at the beginning of the event. On average, mood and the measure of well-being also tended to be on the positive side at the beginning of the event. Student mood and well-being were also higher than average before engaging in any wellness activities. Although it was not feasible to capture a picture of stress, moods, and well-being of the entire student population in this moment, our data suggest that, on average, our participants were experiencing at the very least, better-than-average mental health moments at the time of the event. This may account for why more of the mindfulness activities appeared to be associated with benefits in the short-term (PA) than in the week following (PW).

The challenges of being a university student require the development of coping strategies to manage the tasks of everyday life. In serving students, universities need to provide essential support for mental health and student basic needs (Broton et al. 2022). University students are faced with high demands and new responsibilities and during the COVID-19 pandemic were limited in their access to social support units that were important to their social development and maturation. Hosting student-centered activities and events that focus on mental wellness helps to remove the stigma surrounding mental health issues. Moreover, students who personally address their mental health are strong advocates for other students and change social stigma for the better (Elbulok-Charcape et al. 2021).

Especially now, in the wake of the COVID-19 pandemic, providing resources for social development is necessary for students to learn or relearn resiliency, optimism, and hope (Bagi & Chand 2022). Our study provides evidence of benefits to mental health from mindfulness activities that are enjoyable, are readily accessible with little to no cost, require no particular skill level, and are not time-consuming. We urge universities, in their efforts to promote a culture of resiliency and awareness, to implement these types of mindfulness activities as part of their support for students.

Acknowledgments

This research was supported by the Walter Maxwell Gibson Endowment and L.S. and Aline W. Skaggs Research Endowment funds at Southern Utah University. We would also like to acknowledge the SUU Student Programming Board for assisting with the planning of the Ditch the Stress event.

References

Adair, K.C., Kennedy, L.A., & Sexton, J.B. (2020). Three good tools: Positively reflecting backward and forwards is associated with robust improvements in well-being across three distinct interventions. *The Journal of Positive Psychology*, 15(5), 613-622. <https://doi.org/10.1080/17439760.2020.1789707>.

Bagi, P.D., & Chand, S. (2022). Psychological capital (PsyCap) and mental health among college students. *Indian Journal of Positive Psychology*, 13(4), 432-435.

Boothby, E.J., & Bohns, V.K. (2021). Why a simple act of kindness is not as simple as it seems: Underestimating the positive impact of our compliments on others. *Personality & Social Psychology Bulletin*, 47(5), 826.

Broton, K.M., Mohebbi, M., & Lingo, M.D. (2022). Basic needs insecurity and mental health: Community college students' dual challenges and use of social support. *Community College Review*, 50(4), 456-482. [doi:10.1177/00915521221111460](https://doi.org/10.1177/00915521221111460).

Copeland, E., McGinnis, E., Bai, Y., Adams, Z., Nardone, H., Devadanam, V., Rettew, J., Hudziak, J. (2021). Impact of COVID-19 pandemic on college student mental health and wellness. *Journal of the American Academy of Child & Adolescent Psychiatry*. 60(1): 134-141.

Elbulok-Charcape, M.M., Mandelbaum, F., Miles, R., Bergdoll, R., Turbeville, D., & Rabin, L.A. (2021). Reducing stigma surrounding mental health: Diverse undergraduate students speak out. *Journal of College Student Psychotherapy*, 35(4), 327-344. <https://doi.org/10.1080/87568225.2020.1737853>.

Falon, S.L., Kangas, M., & Crane, M.F. (2021). The coping insights involved in strengthening resilience: The Self-Reflection and Coping Insight Framework. *Anxiety, Stress & Coping*, 34(6), 734-750.

Feeg, V.D., Prager, L.S., Moylan, L.B., Smith, K.M., & Cullinan, M. (2014). Predictors of mental illness stigma and attitudes among college students: Using vignettes from a campus common reading program. *Issues in Mental Health Nursing*, 35(9), 694-703. <https://doi.org/10.3109/01612840.2014.892551>

Grace, M.M., Assalone, A.E., Johnson, H.M., Svoboda, B.L., & Biddix, J.P. (2022). The role of fraternity/sorority affiliation in supporting college student mental health and wellness. *Oracle: The Research Journal of the Association of Fraternity/Sorority Advisors*, 17(2), 19-33. <https://doi.org/10.25774/0jr1-t352>.

Joseph, S., Linley, P.A., Harwood, J., Lewis, C.A., & McCollam, P. (2004). Rapid assessment of well-being: The Short Depression-Happiness Scale (SDHS). *Psychology and Psychotherapy: Theory, Research and Practice*, 77, 463-478.

Kumar, S.A., Edwards, M.E., Grandgenett, H.M., Scherer, L. L., DiLillo, D., & Jaffe, A.E. (2022). Does gratitude promote resilience during a pandemic? An examination of mental health and positivity at the onset of COVID-19. *Journal of Happiness Studies*, 23(7), 3463-3483. <https://doi.org/10.1007/s10902-022-00554-x>.

Liu, C.H., Stevens, C., Wong, S.H., Yasui, M., & Chen, J.A. (2019). The prevalence and predictors of mental health diagnoses and suicide among US college students: Implications for addressing disparities in service use. *Depression and Anxiety*, 36(1), 8-17. <https://doi.org/10.1002/da.22830>.

Rai, S., Mathur, A., & Anshu. (2021). Academic and economical stress levels of college students. *Indian Journal of Health & Wellbeing*, 12(4), 493-496.

Samuel, B., Wang, H., Shi, C., Pan, Y., Yu, Y., Zhu, W., & Jing, Z. (2022). The effects of coloring therapy on patients with generalized anxiety disorder. *Animal Models and Experimental Medicine*, 5(6), 502-512. <https://doi.org/10.1002/ame2.12256>.

Simmons, C. (2016). Effects of coloring on immediate short-term stress relief. Honors Thesis. Oxford, MS: University of Mississippi.

Swarbrick, M. (2006). A wellness approach. *Psychiatric Rehabilitation Journal*, 29(4), 311-314.

Toussaint, L., Nguyen, Q.A., Roettger, C., Dixon, K., Offenbacher, M., Kohls, N., Hirsch, J., & Sirois, F. (2021). Effectiveness of progressive muscle relaxation, deep breathing, and guided imagery in promoting psychological and physiological states of relaxation. *Evidence-Based Complementary and Alternative Medicine*, 2021, 5924040. <https://doi.org/10.1155/2021/5924040>.

Wang, X, Sudeep Hegde, B, Son, C., Keller, B., Smith, A, & Sasangohar, F. (2020). Investigating mental health of US college students during the COVID-19 pandemic: Cross-sectional survey study. *Journal of Medical Internet Research*, 22(9):e22817. <https://doi.org/10.2196/22817>.

Xi, J.Z., Gao, Y.H., Lyu, N., She, Z., Wang, X.Y., Zhang, X.-A., Yu, X.Y., Ji, W.D., Wei, M.S., Dai, W.H., & Qian, X. (2022). Effect of the “art coloring” online coloring game on subjective well-being increase and anxiety reduction during the COVID-19 pandemic: development and evaluation. *JMIR Serious Games*, 10(3), e37026. <https://doi.org/10.2196/37026>.

Supplementary Material

Intake Survey Questions

1. What is your birthday?
2. What are your initials?
3. What is your gender?
4. What is your class standing?
5. Please state your major.
6. How many hours do you spend each week participating in extracurricular activities? (0; 1-2; 3-5; 6+)
7. How many hours a week do you exercise? (0; 1-2; 3-5; 6+)

8. How many hours a day do you spend on your phone? (<1; 1-2; 3-4; 5+)
9. On average, how many full meals do you eat a day? (0; 1; 2; 3; 4+)
10. On average, how many hours of sleep do you get at night? (<4; 4-6; 7-9; 10+)
11. On a scale of 1 - 5 (1 being little/no stress; 5 being high/extreme stress), how would you rate your average level of stress this current semester?
12. On a scale of 1-5 (1 being little/no stress; 5 being high/extreme stress, how would you rate your average level of stress today?
13. On a scale of 1-5 (1 being extremely negative mood; 5 being extremely positive mood), how would you rate your mood right now?
14. A number of statements that people have made to describe how they feel are given below. Please read each one and tick the box that best describes how you felt in the past 7 days, including today. Some statements describe positive feelings and some describe negative feelings. You may have experienced both positive and negative feelings at different times during the past seven days. On a scale of 1-5 (1 being strongly disagree; 5 being strongly agree):
 - I felt dissatisfied with my life.
 - I felt happy.
 - I felt cheerless.
 - I felt pleased with the way I am.
 - I felt that life was enjoyable.
 - I felt that life was meaningless.

Post-Activity Survey Questions

1. What is your birthday?
2. What are your initials?
3. Which activity did you just complete?
4. On a scale of 1-5 (1 being little/no stress; 5 being high/extreme stress, how would you rate your average level of stress right now?
5. On a scale of 1-5 (1 being extremely negative mood; 5 being extremely positive mood), how would you rate your mood right now?

6. A number of statements that people have made to describe how they feel are given below. Please evaluate how you feel right now. On a scale of 1-5 (1 being strongly disagree; 5 being strongly agree):
 - I feel dissatisfied with my life.
 - I feel happy.
 - I feel cheerless.
 - I feel pleased with the way I am.
 - I feel that life was enjoyable.
 - I feel that life was meaningless.

Post-Week Survey Questions

1. What is your birthday?
2. What are your initials?
3. Which activity did you complete throughout this week?
4. How many times this week did you complete this activity since attending the Wellness activity? (1-2; 3-4; 5-6; daily)
5. On a scale of 1-5, 1 being low/little enjoyment, 5 being high/lots of enjoyment, how would you rate your overall level of enjoyment of the activity?
6. On a scale of 1-5 (1 being little/no stress; 5 being high/extreme stress, how would you rate your average level of stress right now?
7. On a scale of 1-5 (1 being extremely negative mood; 5 being extremely positive mood), how would you rate your mood right now?
8. A number of statements that people have made to describe how they feel are given below. Please evaluate how you feel right now. On a scale of 1-5 (1 being strongly disagree; 5 being strongly agree):
 - I feel dissatisfied with my life.
 - I feel happy.
 - I feel cheerless.
 - I feel pleased with the way I am.
 - I feel that life was enjoyable.
 - I feel that life was meaningless.

Examination of the highly variable P8 region (*trnL*-UAA intron) in the genus *Equisetum*

William D. Speer

Salt Lake Community College

Abstract

Sequences covering the highly variable P8 region of the chloroplast trnL-UAA intron from 68 Equisetum specimens representing 17 species and 1 hybrid taxon were examined in this study. P8 sequence lengths ranged from 47 to 82 base pairs. The length variation was mostly due to several, mostly contiguous, indels that were observed among the Equisetum species. One indel reliably separated subgenus Equisetum from subgenera Paramochaete and Hippochaete. P8 structures were consistent among conspecific sequences except for E. palustre. The species E. laevigatum and E. myriochaetum had almost identical P8 secondary structures, as did also E. hyemale/E. praealtum, E. giganteum/E. xylochaetum, E. ramosissimum, and E. variegatum. Sequences had a high average A-T content, ranging from 74.5% to 84.1%. Nucleotide positions toward the middle of the P8 appeared to exhibit higher variability and were more difficult to align while positions closer to the 5' and 3' ends were more conservative and easier to align. The predicted secondary structures for the P8 region tended to be very variable between subgenera and, except for the monotypic subg. Paramochaete, often within. Phylogenetic analyses of the P8 sequences

used the maximum likelihood optimality criterion. Specimens representing subg. *Equisetum* were distinguished from subg. *Hippochaete* and the monotypic subg. *Paramochaete* (*E. bogotense*), with *E. bogotense* nesting in subg. *Hippochaete* in one analysis but with a sister relationship to subg. *Hippochaete* in the other analysis. Although conspecific specimens did group together in many cases, interspecific relationships within subgenera were generally not well resolved and often polytomous. However, P8 data did tend to reliably separate subgenera *Equisetum* and *Hippochaete*, although the position of subg. *Paramochaete* is somewhat questionable.

Introduction

As treated morphologically by Hauke (1963, 1978), the genus *Equisetum* L. was normally recognized as having 15 species. Commonly referred to as either horsetails and scouring rushes, and sometimes as snake grass, these taxa were placed into two subgenera: 1) subg. *Equisetum* (*E. arvense* L., *E. bogotense* Kunth, *E. diffusum* D. Don, *E. fluviatile* L., *E. palustre* L., *E. pratense* Ehrh., *E. sylvaticum* L., and *E. telmateia* Ehrh.) and 2) subg. *Hippochaete* (J. Milde) Baker (*E. giganteum* L., *E. hyemale* L., *E. laevigatum* A. Braun, *E. myriochaetum* Schltdl. & Cham., *E. ramosissimum* Desf., *E. scirpoides* Michx., and *E. variegatum* Schleich. ex Weber & Mohr). In addition to the recognized species, there are also several known hybrids within, but not between, subgenera (Duckett 1979; Des Marais et al. 2003).

Except for one species, several studies using chloroplast DNA sequences have provided support for the placement of *Equisetum* taxa into one of the previously mentioned subgenera. The sole exception to this is the South American species *E. bogotense*, which appears to exhibit a certain degree of phylogenetic lability within the genus, based on the studies of Des Marais et al. (2003) and Guillon (2004, 2007). Utilizing both chloroplast *rbcL* and *trnL-trnF* sequences, Des Marais et al. (2003) first determined that the phylogenetic position of this species was not in subg. *Equisetum* and, conditional on the phylogenetic methodology used, either was in a sister position to subg. *Hippochaete* or was sister to the rest of the genus. A consensus phylogeny presented by this same study placed *E. bogotense* in a basal trichotomy with subg. *Hippochaete* and the rest of subg. *Equisetum* (Des Marais et al. 2003). Furthermore, the *rps4* gene study of Guillon (2004) also tended to place *E. bogotense* not in subg. *Equisetum* but as a sister taxon to the rest of the genus. Guillon (2007) presented an analysis of a combined plastid gene dataset using *trnL-trnF*, *rbcL*, *rps4*, and *atpB* sequences that produced results

basically congruous with results presented by Des Marais et al. (2003) and Guillon (2004), although evaluation of the *atpB* data by itself produced a very different topology that nested *E. bogotense* in subg. *Hippochaete*. The more recent study by Christenhusz et al. (2019) proposed recognition of subg. *Paramochaete* Christenh. & Husby, which is monotypic and consists solely of *E. bogotense*. Their study also splits three of Hauke's (1963, 1978) taxa to arrive at 18 species for the genus (Christenhusz et al. 2019).

This study evaluates the P8 region in the intron of the chloroplast tRNA-*Leu* (*trnL*-UAA) gene of the genus *Equisetum*. The *trnL*-UAA gene is located between the *trnT*-UGU and *trnF*-GAA genes (Figure 1) in the large single-copy region of the chloroplast genome (Quandt and Stech 2004, Won and Renner 2005). The intron, which interrupts the *trnL*-UAA anticodon, is a group I intron and is conserved in both cyanobacteria and plant chloroplasts (Kuhse et al. 1990). Group I introns are characterized by a highly conserved catalytic core that promotes self-splicing from the precursor-tRNA (Cech 1988, Michel and Dujon 1983). According to the secondary structure model of Cech et al. (1994), group I introns have four conserved nucleotide regions, P, Q, R, and S, along with nine stem-loop regions, designated P1 through P9, which fold to form two domains: the P4–P6 domain (from the P4, P5, and P6 helices) and the P3–P9 domain (from the P3, P7, P8, and P9 helices). The P1 contains the short, conserved internal guide sequence (IGS). These intron regions are generally conserved among plants, although the P8 and, sometimes, the P6 regions appear to be much more variable both in terms of length and nucleotide substitutions (Borsch et al. 2003, Quandt et al. 2004, Kishor and Sharma 2018). This conserved structure appears to be necessary for proper RNA splicing (Cech 1990, Michel and Westhof 1990, Michel et al. 1992). Nevertheless, the chloroplast *trnL*-UAA intron in plants seems to have completely lost the ability for self-splicing (Simon et al. 2003).

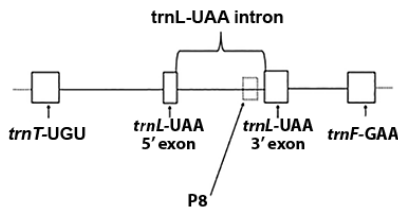


Figure 1. Map showing the position of the *Equisetum* chloroplast *trnL*-UAA gene relative to the *trnT*-UGU and *trnF*-GAA genes. Shown also is the approximate position of the P8 region within the *trnL*-UAA intron.

There have been at least three phylogenetic evaluations of *Equisetum* that, along with other sequence data, have utilized the chloroplast *trnL-trnF* region, which includes the *trnL*-UAA intron (Des Marais et al. 2003, Guillon 2007, Christenhusz et al. 2019). Both Des Marais et al. (2003) and Christenhusz et al. (2019) mention that their sequences do include the *trnL* intron, while Guillon (2007) notes that the *trnL-trnF* used in his study are those of Des Marais et al. (2003). Des Marais et al. (2003) do discuss ambiguously aligned regions of debatable homology, which included portions of the *trnL* intron, and their treatment of these regions, which in some cases involved exclusion from analysis, following Lutzoni et al. (2000). Although not specifically stated as such by Des Marais et al. (2003), it seems likely, for reasons already mentioned, that these *trnL* intron regions of questionable alignment almost certainly include (at least portions of) the P8. Aside from these comments, none of these studies further evaluate the *trnL*-UAA intron, much less the P8 region. Nevertheless, it should be noted that Quandt et al. (2004) includes two *Equisetum* sequences, *E. hyemale* and *E. scirpoides*, in their examination of the *trnL-trnF* region in land plants and make brief comments about the *trnL*-UAA intron with respect to these two species, as well as present the secondary structure of the P8 for *E. hyemale*. Otherwise, they do not go into a detailed examination of the genus. In their phylogenetic analysis of *trnL-trnF* across land plants, Quandt et al. (2004) note that only the more conservative 5' and 3' termini of the P8 regions were included.

Materials and Methods

Specimen selection

Taxa were chosen to include currently recognized *Equisetum* species and one recognized hybrid by using 54 sequences previously deposited in GenBank, as well as 14 sequences generated by the author and newly presented here. Multiple specimen representation of taxa was included for purposes of comparison and insuring accuracy of subsequent *trnL* intron secondary structure determinations. Sequences generated by the author were obtained from either plant material that he personally collected or from material that was provided to him. These were one or more representatives of species *E. arvense*, *E. bogotense*, *E. hyemale*, *E. laevigatum*, *E. myriochaetum*, *E. ramosissimum*, *E. scirpoides*, *E. sylvaticum*, *E. telmateia*, and *E. variegatum*. Also included was a specimen of the hybrid *E. × ferrissii* (*E. laevigatum* × *E. hyemale*). All sequences are listed in Appendix 1 by taxon and GenBank accession number.

DNA extraction, PCR, sequencing, and alignment

For plant material collected by the author or by others, total genomic DNA was extracted using the Doyle and Doyle (1987) CTAB method. Each 100- μ l PCR reaction mixture had 100 ng of DNA. The *trnL*-UAA intron was amplified using Taberlet et al. (1991) forward *c* (5'-CGAAATCGGTAGACGCTACG-3') and reverse *d* (5'-GGGGATA GAGGGACTTGAAC-3') universal primers. Reaction mixtures were heated to 95°C for 5 min, followed by 30 cycles of 95°C (1 min), 42°C (1 min), and 72°C (2 min), concluded by a final extension of 72°C for 10 min, and storage at 4°C in a GeneAmp PCR System 2400 (Perkin-Elmer, Norwalk, CT, USA). A Wizard PCR Prep Purification System (Promega, Madison, WI, USA) was used to purify the PCR products prior to sequencing.

Sequencing reactions used BigDye Terminator Cycle Sequencing Ready Reaction (PE Applied Biosystems, Foster City, CA, USA). Sequencing reactions were heated to 96°C for 1 s, followed by 30 cycles of 96°C (1 s), 47°C (5 s), and 60°C (4 min), and then stored at 4°C. Reactions were cleaned using Sephadex columns, loaded onto an acrylamide gel, and electrophoresed on an ABI Prism 377 DNA Sequencer (PE Applied Biosystems). Sequences that were generated were deposited in GenBank and assigned accession numbers.

Sequences were initially aligned using MUSCLE (Edgar 2004a, b), followed by manual editing. It has been recognized that editing, whether manually or by other software, of alignments generated by computer programs is often necessary for several reasons, including 1) most alignment programs use a heuristic methodology that may not necessarily find the optimal solution, and 2) some programs will generate ambiguous alignments or numerous gaps between nucleotide regions (Goode and Rodrigo 2007). Manual editing of the P8 sequences here, however, was very minimal. Nucleotide variation, including the number of variable and informative sites, was evaluated using MEGA X (ver. 10.0.5) (Kumar et al. 2018), particularly in the P8 region, to identify variable sites. P8 length variation was evaluated and recorded.

Determination of trnL-UAA intron secondary structure for Equisetum

Because of the highly conserved structural nature of the catalytic core in group I introns, the positions of the individual P1 through P9 stem-loop regions of the *trnL*-UAA intron were identified relative to the conserved P, Q, R, and S regions through comparison of *Equisetum* sequences with the published *trnL*-UAA intron secondary structures for

Nymphaea odorata Aiton (Borsch et al. 2003), *Chaetosphaeridium globosum* (Nordstedt) Klebahn (Quandt et al. 2004), *Campylopus flexuosus* (Hedw.) Brid. (Quandt and Stech 2005), and the Faboideae subfamily (D'yachenko et al. 2015).

Once these regions were identified for *Equisetum*, the mFold RNA folding form v2.3 (Zuker 2003; www.unafold.org) was employed to produce individual RNA foldings of the P1; P2; combined P4, P5, and P6; P8; and P9 regions. A temperature setting of 25°C was used, but default settings were otherwise used. Determination of these individual secondary structures facilitated subsequent prediction of the P3 and P7 structures. Finally, all these individual secondary structures, minus P8, were joined to construct the overall *trnL*-UAA intron secondary structure for the genus. Included in the resulting *trnL*-UAA secondary structure are the last 3 nucleotides of the 5' exon and the first 4 nucleotides of the 3' exon because the ends of both exons are considered to play roles in secondary structural formation or excision and splicing and are catalytically involved with the IGS (Karbstein et al. 2007). For the individual species P8 secondary structures, the RnaViz.ct files provided by mFold were saved and then processed by the drawing program RnaViz2 (De Rijk et al. 2003).

The resulting intron secondary structure (minus P8) was also evaluated for any possible compensatory base changes (CBCs) and hemi-CBCs (hCBCs). CBCs are substitutions that affect both nucleotides at a paired position but still maintain the paired nucleotide bond; hCBCs maintain the nucleotide bond while affecting only one nucleotide (Ruhl et al. 2010, Li et al. 2019). It should be noted, however, that CBCs are generally not found at the generic level or lower but are found more frequently at higher systematic levels (Quandt et al. 2004). Because of indels causing length variation in the P8 region (see Results), the P8 region was not evaluated for the presence of CBCs or hCBCs because it could not be reliably determined that base pairing relationships were always the same between P8 sequences evaluated.

Phylogenetic analysis of P8 nucleotide data

As already noted, previous phylogenetic analyses using different chloroplast DNA sequences have tended to place taxa into 2 or 3 subgenera within the genus *Equisetum*. At the same time, and depending on the methodology employed, different relationships among taxa have been observed, particularly the phylogenetic lability of *E. bogotense*. To further evaluate P8 relationships within *Equisetum*, two phylogenetic approaches were employed using both the Phylogeny.fr website (Dereeper et al. 2008, http://phylogeny.lirmm.fr/phylo_cgi/index.cgi)

and MEGA X. P8 sequences were evaluated at the Phylogeny.fr website by selecting “One Click” option and with the Gblocks option deselected. The “One Click” option generated trees using maximum likelihood and selected the HKY85 substitution model, with the estimated proportion of invariant sites, and four gamma-distributed rate categories, or HKY+G+I, as implemented in PhyML (Guindon et al. 2010). Note that internal branch reliability was evaluated using the approximate likelihood ratio test (aLRT) (Anisimova and Gascuel 2006). Phylogenetic trees were generated using Tree Dyn (Chevenet et al. 2006).

Phylogenetic analysis of the P8 region was also performed with MEGA X (ver.10.2.6). In MEGA, the Jukes-Cantor model with invariant sites (JC+I) was chosen using the “Models” drop-down box and selecting “Find best DNA/protein models (ML)” option and then subsequently choosing “Partial deletion” in the “Gaps/missing data treatment” drop-down menu. Maximum likelihood analyses were performed with bootstrapping (500 repetitions) and partial deletion. All branches with a bootstrap support of less than 50% were collapsed. A midpoint rooting approach was used in MEGA X because a suitable plant outgroup could not be reliably determined using BLAST (Altschul et al. 1997).

Results

trnL-UAA intron sequences

The 14 sequences obtained by the author varied in length from 158 base pairs (bp) to 338 bp. Except for the sequence for *E. scirpoides*, all sequences included portions of the flanking 5' and 3' exons and the entire *trnL-UAA* intron. The 14 sequences by taxon (and GenBank accession number) are for *E. hyemale* (OQ971731), 2 specimens of *E. arvense* (OQ971732 and OQ971739), *E. bogotense* (OQ971733), 2 specimens of *E. variegatum* (OQ971734 and OQ971744), *E. sylvaticum* (OQ971735), *E. myriochaetum* (OQ971736), 2 specimens of *E. telmateia* (OQ971738 and OQ971741), *E. ramosissimum* (OQ971740), *E. laevigatum* (OQ971742), *E. scirpoides* (OQ971743), and *E. × ferrissii* (OQ971737). These and the 54 downloaded sequences are listed in Appendix 1. For the 68-sequence dataset, complete intron and P8 lengths varied for *Equisetum*, ranging from 234 nucleotides (nt) and 47 nt (all *E. sylvaticum*), respectively, to 269 nt and 82 nt (one of the downloaded *E. palustre* sequences (GQ244925)). All sequences had the complete P8, with the observed length variation due to mostly contiguous indels in the middle of this region. In general, conspecific sequences were identical to each other. However, the three downloaded *E. palustre* sequences differed noticeably among each other. Though almost identical, two

downloaded *E. arvense* sequences shared an extra nucleotide (A) not in the other sequences for this species. Between *E. variegatum* sequences, there were 3 distinct substitutions. For these last two taxa, the aforementioned nucleotide variation resulted in no or very minor secondary structural variation (see below). A two-adenine nucleotide deletion segregated subg. *Equisetum* from subgenera *Paramochaete* and *Hippochaete*.

Most of the observed nucleotide variation (62.7%) for the intron was in the P8 region. Not counting gaps, this means that the approximately 187 nucleotide positions outside of the P8 were less variable than the 47 to 82 positions that comprise the P8. For the overall intron, there were 51 positions that were variable, of which 44 were phylogenetically informative. For the P8, 32 positions were variable, of which 31 were informative. P8 sequences were A-T rich. A-T content ranged from 74.5% (*E. sylvaticum*) to 84.1% (one of the *E. pratense*). The average was 79.3%. Nucleotide positions toward the middle of the P8 appeared to exhibit higher variability and were more difficult to align while positions closer to the 5' and 3' ends were more conservative and easier to align. The P8 sequences for *E. giganteum* and *E. xylochaetum* were identical, as were those for *E. hyemale* and *E. praealtum*.

Secondary structure

A general secondary structure was predicted for the intron minus the P8 and the individual P8 secondary structures for each taxon. The intron secondary structure shown in Figure 2 uses *E. arvense* as a template and indicates nucleotide variation for the other *Equisetum* taxa. As expected, there were not any CBCs found between the taxa in the genus *Equisetum* for the *trnL*-UAA intron. However, two instances of hCBCs (A-U ↔ G-U) were found in the P1, one of which involved the IGS (Figure 2). Additionally, three possible A-G pairings (see Leonard et al. 1994, Ito and Mizutani 2001, Ito et al. 2004) for some species were observed in the P6 (two) and P8.0 regions (one), which may be hCBCs also. These A-G pairings were not further evaluated in this study.

Based on this, nucleotide variation between taxa would have resulted in a minimal amount of secondary structural variation at five nucleotide positions with regards to the intron minus the P8. In contrast, there were perceptible differences between P8 secondary structures of the differing taxa, both between and within subgenera. The obtained P8 region secondary structures for *Equisetum* species are presented in Figures 3 through 6.

It should be noted that most of the subg. *Hippochaete* taxa had identical or very similar P8 secondary structures. Although there was

some nucleotide variation between taxa, and occasionally within the same taxon, P8 secondary structures for *E. scirpoides*, *E. giganteum*/*E. xylochaetum*, *E. hyemale*/*E. praealtum*, and *E. ramosissimum* were

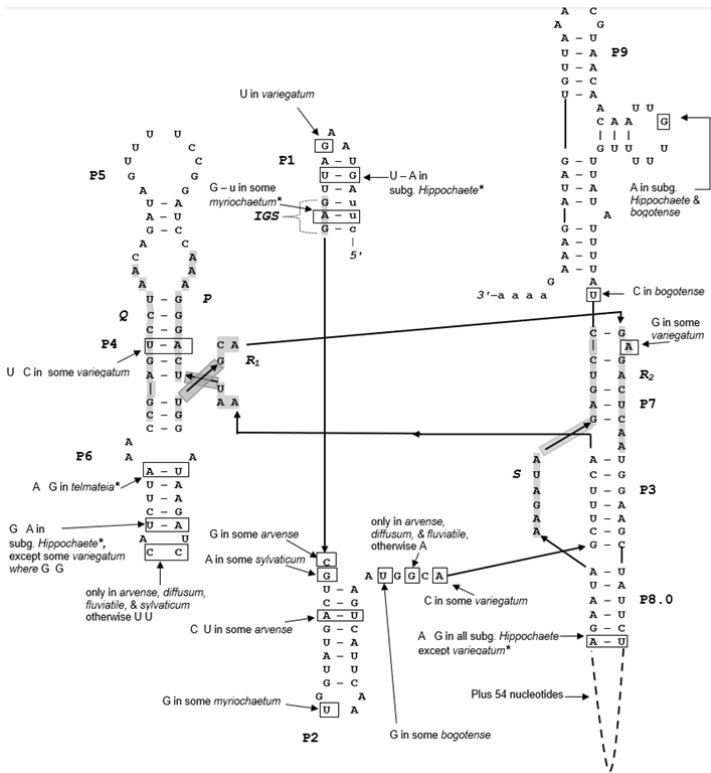


Figure 2. Predicted secondary structure of the trnL-UAA intron minus P8 (P8 shown separately for each species) following the group I intron secondary structure model of Cech et al. (1994). Shown in their entirety are the P1 through P7 and P9 stem loop regions. Only the basal portion of the P8 stem loop is shown here. Also indicated are the conserved P, Q, R, and S regions and the internal guide sequence (IGS). The secondary structure shown is for *E. arvense* (specimen Eq_arvensel) with nucleotide variants for other taxa displayed. Lowercase letters are exon nucleotides. *=hCBC or possible hCBC.

almost identical. *E. variegatum* was also very similar, but had an extra nucleotide in its terminal loop. Also in subg. *Hippochaete*, *E. myriochaetum* and *E. laevigatum* shared a common structure that was different from the other species.

In general, all P8 secondary structures were similar as far as the basal portion of the secondary structure formed by 10 nt in terminal positions on each of the 5' and 3' ends of the P8 region. This is

subg. *Hippochaete*

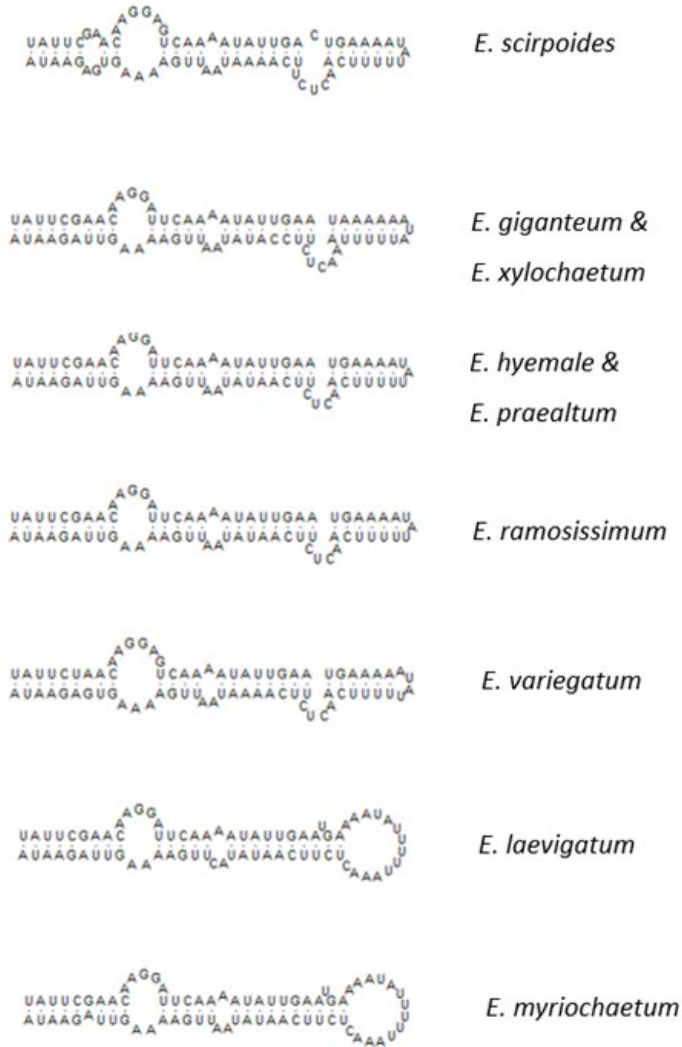
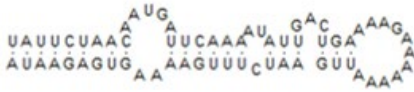
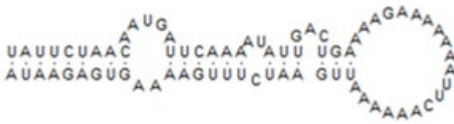


Figure 3. Predicted secondary structures for the P8 region of the *trnL*-UAA intron for subg. *Hippochaete*.

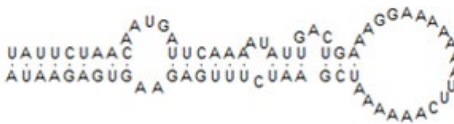
subg. *Equisetum*



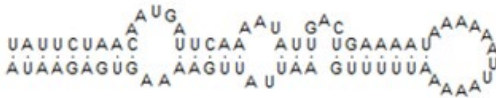
E. arvense



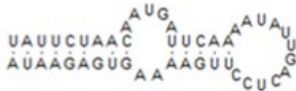
E. diffusum



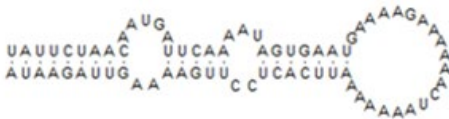
E. fluviatile



E. pratense



E. sylvaticum



E. telmateia

Figure 4. Predicted secondary structures for the P8 region of the *trnL*-UAA intron for subg. *Equisetum*, except for *E. palustre* structures (see Figure 5).



Figure 5. The predicted secondary structures for the P8 region of the *trnL*-UAA intron for *E. palustre* (subg. *Equisetum*). *E. palustre* was the only species that was highly variable for conspecific sequences.

Subg. *Paramochaete*

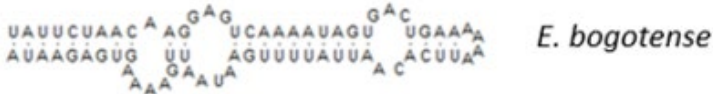


Figure 6. Predicted secondary structure for the P8 region of the *trnL*-UAA intron for the monotypic subg. *Paramochaete*.

immediately followed by an internal loop that varied in size between taxa by up to 3 single nucleotides. The only exception to this general pattern was among the structure for the 3 downloaded *E. palustre* (subg. *Equisetum*) sequences, which were not only distinct from the other *Equisetum* sequences but were the only set of conspecific sequences that were mostly not similar to each other. *E. palustre* secondary structures were not further analyzed. Otherwise, minor or no secondary structural variation was observed for conspecific specimens (see *E. arvense* and *E. variegatum* above). For most taxa, there were second and third internal loops that appeared at approximately the same structural position, though sometimes with structural, nucleotide, and/or length variation. The

hairpin loop differed in size between groups of taxa, both between and within subgenera. Aside from the anomalous *E. palustre* sequences, the exceptions to this were *E. bogotense* (second internal loop in different position), *E. laevigatum* and *E. myriochaetum* (side bulge instead of third internal loop), *E. sylvaticum* (shorter sequence), and *E. telmateia* (missing third internal loop). Except for the monotypic subg. *Paramochaete*, all taxa within the same subgenus did not share a common P8 secondary structure. However, there were one or more groups of taxa within subgenera that had similar secondary structures. Two distinct groups were observed in subg. *Hippochaete*. The first group was the larger and was comprised of *E. scirpoides*, *E. variegatum*, *E. ramosissimum*, *E. hyemale*, *E. praealtum*, *E. giganteum*, and *E. xylochaetum*. This group had overall similar secondary structures, although with minor variations, mostly in or around loop regions. The most variable member of this group was *E. scirpoides*, which had a smaller extra internal loop but was otherwise more similar to members of this group than to the second group. The second group within subg. *Hippochaete* consisted of *E. laevigatum* and *E. myriochaetum* only, which had basically identical secondary structures and whose sequences only differed at one nucleotide position their second internal loop. For subg. *Equisetum*, *E. arvense*, *E. diffusum*, *E. fluviatile*, and *E. pratense* had very similar, although not identical secondary structures. *E. telmateia* and *E. sylvaticum* each had different P8 secondary structures.

Two sequences of the hybrid *E. × ferrissii* (*E. laevigatum* × *E. hyemale*) were included in this study. These differed with respect to secondary structure. The secondary structure for the *E_x_ferrissii1* sequence was identical with that for *E. laevigatum*, whereas *E_x_ferrissii2* was the same as the *E. hyemale* secondary structure.

Phylogenetic analysis of P8 nucleotide data

The PhyML analysis produced results comparable with previous studies (see Introduction and Discussion) and with subg. *Equisetum* clearly distinct from the other two subgenera (Figure 7). Furthermore, subg. *Paramochaete* was placed in a sister position to subg. *Hippochaete*. In general, conspecific specimens grouped or, in other cases, specimens of closely related taxa formed clades. The two specimens of the hybrid *E. × ferrissii* grouped differently, apparently according to chloroplast parental taxon, with specimen *E_x_ferrissii1* grouping with the *E. laevigatum* specimens and *E_x_ferrissii2* with the *E. hyemale* sequences. In this evaluation, aLRT branch support ranged from 0.592 to 0.998. The two main groupings, subg. *Equisetum* and subg. *Paramochaete/Hippochaete* were both separated with aLRT = 0.9.

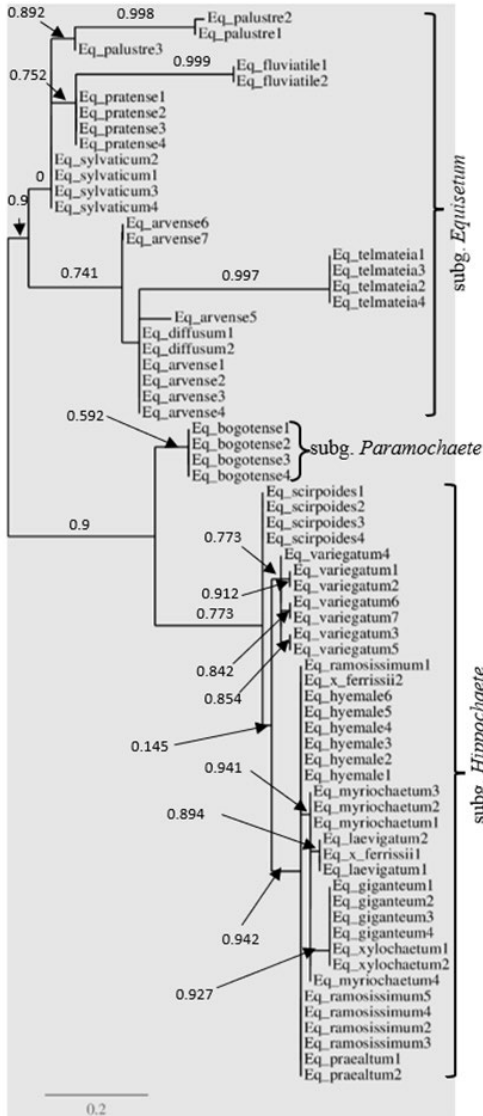


Figure 7. PhyML analysis using maximum likelihood (HKY + G + I substitution model). Internal branch reliability was evaluated using the approximate likelihood ratio test.

The ML tree produced by MEGA X (Figure 8) plainly separated subg. *Equisetum* from the other two subgenera. However, subg.

Paramochaete was clearly nested in subg. *Hippochaete*. Although there was some grouping of conspecific specimens or of closely related taxa, most specimens in subg. *Hippochaete* were in a polytomous relationship (including the two *E. × ferrissii* of different maternal affiliations) with only specimens for *E. scirpoides* and for *E. variegatum* forming distinct species groupings. Although they grouped distinctly from each other, *E. bogotense* (subg. *Paramochaete*), *E. scirpoides*, and *E. variegatum* were united in a clade and were separate from the other subg. *Hippochaete* specimens. For subg. *Equisetum*, sequences for *E. telmateia*, *E. pratense*, *E. sylvaticum*, *E. fluviatile*, and *E. palustre* grouped according to conspecific affiliation. In contrast, all sequences for *E. arvense* and *E. diffusum* formed a clade with *E. fluviatile*. In this analysis, branch support for the subg. *Hippochaete* (minus *E. scirpoides* and for *E. variegatum*) clade and the *E. telmateia* clade was very strong at 95% each. Otherwise, branch support values in this phylogenetic tree were weak to moderate (62% to 86%). The results of the PhyML analysis could not be precisely duplicated using HKY + G + I in MEGA X, most likely because of differences in algorithms and available settings.

Discussion

Nucleotide variation and secondary structure

Both the *Equisetum* overall intron and the P8 region are short as compared with other plant taxa. In their survey of land plants, which included bryophytes, lycophytes, ferns, gymnosperms, and angiosperms, Quandt et al. (2004) reported that the *trnL* intron ranged from 218 bp to 660 bp, with an average length of 443.7 bp. In this same study, P8 lengths ranged from 26 bp to 360 bp, with an average of 213.9 bp. Comparable values to those from Quandt et al. (2004) for the *trnL*-UAA intron were found in the basal angiosperm study by Borsch et al. (2003). Thus, it would seem that *Equisetum* falls toward the smaller ends of the reported intron and P8 length ranges. It should be noted that Quandt et al. (2004) included *E. hyemale* and *E. scirpoides* in their study (but not any other *Equisetum* species). They reported that among tracheophytes, *Equisetum* had noticeably shorter *trnL*-UAA introns, and the present study would seem to agree with that assessment. In their discussion, the lower end of the intron length was reported as being around 218 bp, and they appeared there to include *Equisetum* (Quandt et al. 2004). However, the lengths of intron determined here and compared with the provided sequence information in GenBank (e.g., the published *Equisetum* complete chloroplast genomes) indicate longer intron lengths. Even the aforementioned *E. sylvaticum* intron was slightly longer.

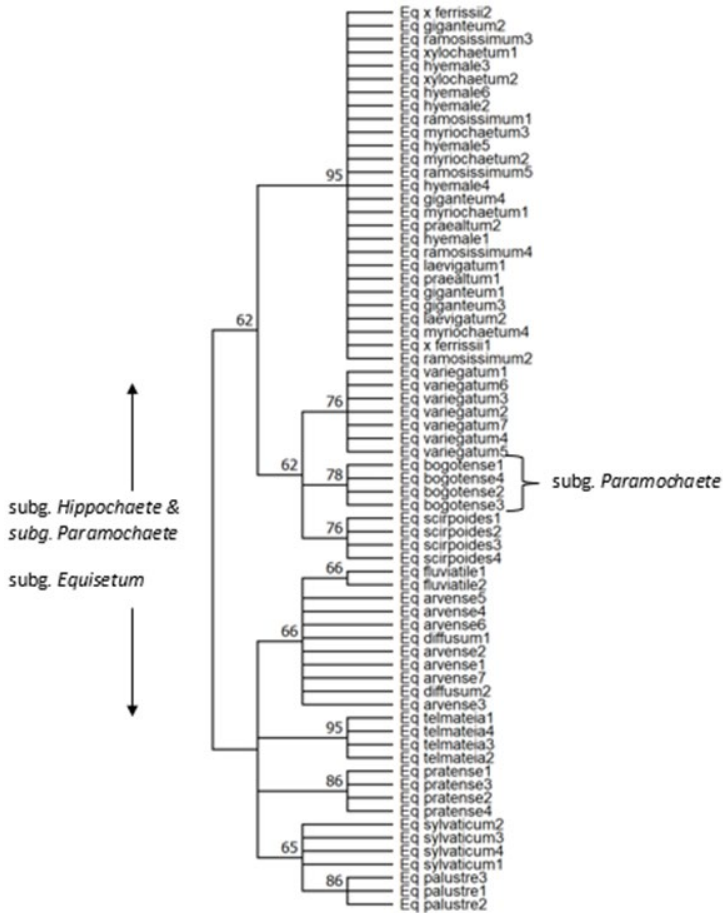


Figure 8. ML tree obtained using the MEGA X program (JC+I substitution model). A midpoint rooting approach was utilized. All branches with a bootstrap support of less than 50% were collapsed.

Similar to previous studies, most of the nucleotide variation was in the P8 area and as for other plant groups investigated (Borsch et al. 2003, Quandt et al. 2004), the P8 region had a high A-T content. In their respective papers, Borsch et al. (2003) and Quandt et al. (2004) proposed that both the observed A-T richness of the P8 and the length variation of the P8 are due to slipped strand mispairing events, which are a type of mutational occurrence that happens during DNA replication and results in the mispairing of DNA strands (Levinson and Gutman, 1987). These

same studies (Borsch et al. 2003, Quandt et al. 2004) have reported that the P6 region is sometimes also a source of considerable mutational and length variation, although these were looking at deeper phylogenetic levels. At any rate, although there was some nucleotide variation observed for the P6 among *Equisetum*, no length variation was found.

For *Equisetum*, the nucleotide variation in the *trnL*-UAA intron minus P8 resulted in no or, at most, very minor secondary structural variation between species. Five nucleotide positions resulted in minimal structural variation. In general, intron secondary structure appeared to be conserved among all *Equisetum* sequences. The IGS (in P1) was GAG for most *Equisetum* sequences but was GGG for two *E. myriochaetum* specimens. The IGS is usually GRG (R = A or G), with GAG appearing in >95% of all examined sequences (Quandt and Stech, 2005). As part of the P1 stem of group I introns, the IGS is required for correct alignment of the 5' exon through base pairing and then is later involved with the formation of a P10 helix with the 3' exon during RNA excision and splicing (Karbstein et al. 2007). Nevertheless, the plant chloroplast *trnL*-UAA intron appears to have totally lost the ability for self-splicing and may be dependent on a nuclear factor to enable excision (Simon et al. 2003).

As expected, there were not any observed CBCs in the intron minus P8. This is consistent with previous observations that CBCs are not normally found among congeneric taxa (Quandt et al. 2004, Quandt and Stech, 2005, Li et al. 2019). However, there are exceptions. For example, they have been reported in the secondary structures of ITS2 for insect species in the genus *Altica* (Ruhl et al. 2010) and in the *trnL*-UAA intron (P2) of species in the hornwort genus *Anthoceros* L. (Stech et al. 2003). Two, possibly five (see Results), hCBCs were observed for the chloroplast *trnL*-UAA intron minus P8 for *Equisetum*. For those studies examined, whenever both CBCs and hCBCs were reported at various systematic levels, hCBCs were more frequent (Stech et al. 2003, Ruhl et al. 2010, Nanjappa et al. 2013, Montelli et al. 2016, Zapelloni et al. 2021).

That *E. laevigatum* and *E. myriochaetum* had basically identical secondary structures (although with nucleotide variation) that distinguished them from other taxa in subg. *Hippochaete* is not completely surprising. Previous phylogenetic studies (Des Marais et al. 2003, Guillon 2004, 2007 (combined gene analysis), Christenhusz et al. 2019) have suggested a close phylogenetic relationship between these species. Furthermore, Des Marais et al. (2003) identified these species as the most derived species pair in subg. *Hippochaete*. In subg. *Equisetum*, *E. arvense*, *E. diffusum*, and *E. fluviatile* had similar P8 secondary structures. *E. arvense* has a shorter P8 sequence and mainly differed from

the other two in terms of the size of the hairpin. These three taxa have also grouped together in previous systematic analyses of the genus (Des Marais et al. 2003, Guillon 2004, 2007, Christenhusz et al. 2019). However, even though *E. pratense* had a similar secondary structure with these three taxa, it was distinct from them.

Different secondary structures were obtained for each of the 2 *E. x ferrissii* sequences, with the secondary structure of specimen E_x_ferrissii1 being the same as that obtained for *E. laevigatum*. On the other hand, E_x_ferrissii2 shared a common secondary structure with *E. hyemale*. This is perhaps not that surprising. *E. x ferrissii* is known to be a sterile hybrid between *E. laevigatum* x *E. hyemale* (Moran 1983). Chloroplast inheritance in ferns examined to date is maternal (e.g., Gastony and Yatskievych 1992, Vogel et al. 1998, Renzaglia et al. 2002, Kuo et al. 2018). It would appear that the different secondary structures obtained for the two *E. x ferrissii* hybrids are indicative of the maternal taxon.

Aside from P8, the only intron region that is often considered highly variable is P6 (e.g., Borsch et al. 2003, Quandt et al. 2004). However, this region showed minimal nucleotide and secondary structural variation among the *Equisetum* sequences examined here.

Extremely minor nucleotide sequence and secondary structural variation was sometimes seen between conspecific specimens. However, the distinct P8 nucleotide sequences and resulting divergent secondary structures for *E. palustre* are problematic. Although these sequences were still more similar to each other than to other species, their secondary structures were quite different. Further evaluation of the P8 region in *E. palustre* is needed.

Phylogenetic analyses

The different substitution models and measures of branch support/reliability implemented in the PhyML and MEGA X approaches were employed to evaluate the phylogenetic relationships based on nucleotide data in this study. The results obtained from each were in general agreement as to the separation of subgenera *Equisetum* and *Hippochaete*. As has been seen when comparing different studies and approaches, however, the relationship of subg. *Paramochaete* with these other two subgenera is not clear. With respect to phylogenetic relationships between species within subgenera (except subg. *Paramochaete*), the two methodologies employed differed on some points with respect to resolution and/or the actual relationships observed, although there were also similarities.

At least some of the differences between the PhyML and the MEGA X results might be explained as due to the differences in the substitution models selected by these programs. Although both were used to evaluate the same data set for ML analysis, they each selected different nucleotide substitution models. As implemented by the “One click” mode at the Phylogeny.fr website (Dereeper et al. 2008), PhyML selected an HKY+G+I model only. In contrast, MEGA X selected a JC+I model. Although model selection is usually considered a necessary aspect of phylogenetic analysis, it should be remembered that these models are, at best, hypotheses and approximations (Abadi et al. 2019). Furthermore, the criteria used for model selection are not without some discussion and continued examination (e.g., Posada and Buckley 2004, Luo et al. 2010, Liu et al. 2023), and it has even been recently suggested that model selection may not be as necessary as previously thought (Abadi et al. 2019). Nevertheless, the use of various models does provide a framework to investigate evolutionary relationships. The use of these two models permitted the evaluation of two different possible phylogenetic patterns in the P8 nucleotide data.

Although both approaches separated the subg. *Equisetum* from the other two subgenera, the placement of monotypic subg. *Paramochaete* (= *E. bogotense*) differed between the two approaches. In the PhyML tree, *E. bogotense* was in a sister relationship with subg. *Hippochaete*, which was consistent with some phylogenetic results reported by Des Marais et al. (2003), who first reported on the phylogenetic lability of this species, and the multigene phylogeny presented by Guillon (2007). In contrast, MEGA X results had *E. bogotense* nesting within subg. *Hippochaete*, which is similar to the *atpB*-only portion of the Guillon (2007) study (although grouping with some different taxa). Other studies have placed *E. bogotense* in a sister position to the rest of the genus (e.g., Guillon 2004, Christenhusz et al. 2019). Consistent with the MEGA X results obtained here, previous studies (Des Marais et al. 2003, Guillon 2004, 2007, Christenhusz et al. 2019) have tended to group *E. arvense*, *E. diffusum*, and *E. fluviatile*. In contrast, the PhyML results acquired in this study had *E. fluviatile* well separated from the other two taxa. The PhyML results, but not the MEGA X, also grouped differently the two sequences for the hybrid *E. × ferrissii* according to maternal (chloroplast parental) taxon, which corresponds to the reported secondary structure results for these two specimens.

Conclusion

Secondary structure analysis appeared to be useful, to some degree, for identifying subgeneric relationships within the genus *Equisetum*.

With the exception of the previously mentioned *E. palustre*, conspecific sequences had identical or nearly identical secondary structures. Furthermore, it was observed that closely related species within subgenera had identical or, at least, very similar secondary structures (e.g., *E. myriochaetum* and *E. laevigatum*). The phylogenetically labile *E. bogotense* (subg. *Paramochaete*) notwithstanding, the P8 sequence data appear to be generally useful for distinguishing subgenera and, depending on the approach and substitution model employed, may be useful in distinguishing individual species. For the two *E. × ferrissii* specimens, both secondary structural and phylogenetic analyses (here, PhyML) grouped sequences according to maternal species relationships, which is suggestive of its possible applicability in plant hybrid studies. Overall, P8 does certainly appear to be useful for identifying subgeneric relationships and sometimes species within the genus *Equisetum*. This was clearly implied by the secondary structures obtained in this study and the phylogenetic analysis of the sequence data.

Acknowledgements

I thank Dr. Paul Wolf, then in the Biology Department of Utah State University, for use of space and equipment, and particularly for allowing me to use the departmental ABI Prism 377 DNA Sequencer. This study was partially funded (sequencing reagents) by a Sigma Xi Grant in Aid of Research.

Literature Cited

- Abadi S, Azouri D, Pupko T, Mayrose I. 2019. Model selection may not be a mandatory step for phylogeny reconstruction. *Nat Commun* 10:934.
- Altschul SF, Madden TL, Schäffer AA, Zhang J, Zhang Z, Miller W, Lipman DJ. 1997. Gapped BLAST and PSI-BLAST: a new generation of protein database search programs. *Nucleic Acids Res* 25:3389–3402.
- Anisimova M, Gascuel O. 2006. Approximate likelihood ratio test for branches: A fast, accurate and powerful alternative. *Syst Biol* 55:539–552.
- Borsch T, Hilu KW, Quandt D, Wilde V, Neinhuis C, Barthlott W. 2003. Noncoding plastid *trnT-trnF* sequences reveal a well resolved phylogeny of basal angiosperms. *J Evol Biol* 16:558–576.

Cech TR. 1988. Conserved sequences and structures of group I introns: building an active site for RNA catalysis—a review. *Gene* 73:259–271.

Cech TR. 1990. Self-splicing of group I introns. *Annu Rev Biochem* 59:543–568.

Cech TR, Damberger SH, Gutell R. 1994. Representation of the secondary and tertiary structure of group I introns. *Nat Struct Biol* 1: 273–280.

Chevenet F, Brun C, Banuls AL, Jacq B, Chisten R. 2006. TreeDyn: towards dynamic graphics and annotations for analyses of trees. *BMC Bioinform* 7:439.

Christenhusz MJM, Bangiolo L, Chase MW, Fay MF, Husby C, Witkus M, Viruel J. 2019. Phylogenetics, classification and typification of extant horsetails (*Equisetum*, Equisetaceae). *Bot J Linn Soc* 189:311–352.

De Rijk P, Wuyts J, De Wachter R. 2003. RnaViz2: an improved representation of RNA secondary structure. *Bioinformatics* 19:299–300

Dereeper A, Guignon V, Blanc G, Audic S, Buffet S, Chevenet F, et al. 2008. Phylogeny.fr: robust phylogenetic analysis for the non-specialist. *Nucleic Acids Res* 36:W465–469.

Des Marais DL, Smith AR, Britton DM, Pryer KM. 2003. Phylogenetic relationships and evolution of extant horsetails, *Equisetum*, based on chloroplast DNA sequence data (*rbcL* and *trnL-F*). *Int J Plant Sci* 164:737–751.

Doyle JJ, Doyle JL. 1987. A rapid DNA isolation procedure for small quantities of fresh leaf tissue. *Phytochem Bull* 19:11–15.

Duckett JG. 1979. An experimental study of the reproductive biology and hybridization in the European and North American species of *Equisetum*. *Bot J Linn Soc* 79:205–229.

D'yachenko EA, Filyushin MA, Pronin EP, Kochieva EZ. 2015. Variability of the *trnL* plastid gene's intron in the Faboideae species (Fabaceae). *Russ J Genet Appl Res* 5: 220–226.

Edgar RC. 2004a. MUSCLE: multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Res* 32:1792–1797.

Edgar RC. 2004b. MUSCLE: a multiple sequence alignment method with reduced time and space complexity. *BMC Bioinform* 19:113.

Gastony GJ, Yatskievych G. 1992. Material inheritance of the chloroplast and mitochondrial genomes in cheilanthoid ferns. *Am J Bot* 79:716–722.

Goode MG, Rodrigo AG. 2007. SQUINT: a multiple alignment program and editor. *Bioinformatics* 23:1553–1555.

Guillon J-M. 2004. Phylogeny of horsetails (*Equisetum*) based on the chloroplast *rps4* gene and adjacent noncoding sequences. *Syst Bot* 29:251–259.

Guillon J-M. 2007. Molecular phylogeny of horsetails (*Equisetum*) including chloroplast *atpB* sequences. *J Plant Res* 4:569–574.

Guindon S, Dufayard JF, Lefort V, Anisimova M, Hordijk W, Gascuel O. 2010. New algorithms and methods to estimate maximum-likelihood phylogenies: assessing the performance of PhyML 3.0. *Syst Biol*. 2010 59:307–21.

Hauke RL. 1963. A taxonomic monograph of the genus *Equisetum* subgenus *Hippochaete*. *Nova Hedwigia* 8:1–123.

Hauke RL. 1978. A taxonomic monograph of *Equisetum* subgenus *Equisetum*. *Nova Hedwigia* 30:385–455.

Ito Y, Mizutani T. 2001. Evidence of G-A/A-G pair, not A-G/G-A pair, in SECIS element. *Nucleic Acids Res Suppl* (1):41-42.

Ito Y, Sone Y, Mizutani T. 2004. Stability of non-Watson-Crick G-A/A-G base pair in synthetic DNA and RNA oligonucleotides. *Mol Biol Rep* 31:31-36.

Karbstein K, Lee J, Herschlag D. 2007. Probing the role of a secondary structure element at the 5'- and 3'-splice sites in group I intron self-splicing: the *Tetrahymena* I-16 *Scal* ribozyme reveals a new role of the G·U pair in self-splicing. *Biochem* 46:4861–4875.

Kishor R, Sharma GJ. 2018. The use of the hypervariable P8 region of *trnL* (UAA) intron for identification of orchid species: Evidence from restriction site polymorphism analysis. *PLoS ONE* 13:e0196680.

Kuhse MG, Strickland R, Palmer JD. 1990. An ancient group I intron shared by eubacteria and chloroplasts. *Science* 250:1570–1573.

Kumar S, Stecher G, Li M, Knyaz C, Tamura K. 2018. MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. *Mol Biol Evol* 35:1547–1549.

Kuo LY, Tang TY, Li FW, Su HJ, Chiou WL, Huang YM, Wang CN. 2018. Organelle genome inheritance in *Deparia* ferns (Athysariaceae, Aspleniales). *Front Plant Sci* 9:486.

Leonard GA, McAuley-Hecht KE, Ebel S, Lough DM, Brown T, Hunter WN. 1994. Crystal and molecular structure of r(CGCGAAUUAGCG): an RNA duplex containing two G(anti).A(anti) base pairs. *Structure* 2:483–494.

Levinson G, Gutman GA. 1987. Slipped-strand mispairing: a major mechanism for DNA sequence evolution. *Mol Biol Evol* 4:203–221.

Li M, Zhao H, Zhao F, Jiang L, Peng H, Zhang W, Simmons MP. 2019. Alternative analyses of compensatory base changes in an ITS2 phylogeny of *Corydalis* (Papaveraceae). *Ann Bot* 124:233–243.

Liu Q, Charleston MA, Richards SA, Holland BR. 2023. Performance of Akaike Information Criterion and Bayesian Information Criterion in Selecting Partition Models and Mixture Models. *Syst Biol* 72:92–105.

Luo A, Qiao H, Zhang Y, et al. 2010. Performance of criteria for selecting evolutionary models in phylogenetics: a comprehensive study based on simulated datasets. *BMC Evol Biol* 10:242.

Lutzoni F, Wagner P, Reeb V, Zoller S. 2000. Integrating ambiguously aligned regions of DNA sequences in phylogenetic analyses without violating positional homology. *Syst Biol* 49:628–651.

Michel F, Dujon B. 1983. Conservation of RNA secondary structures in two intron families including mitochondrial-, chloroplast-, and nuclear-encoded members. *EMBO J* 2:33–38.

Michel F, Westhof E. 1990. Modelling of the three-dimensional architecture of group I catalytic introns based on comparative sequence analysis. *J Mol Biol* 216:585–610.

Michel F, Jaeger L, Westhof E, Kuras R, Tihy F, Xu MQ, Shub DA. 1992. Activation of the catalytic core of a group I intron by a remote 3' splice junction. *Genes Dev* 6:1373–1385.

Montelli S, Peruffo A, Patarnello T, Cozzi B, Negrisolo E. 2016. Back o water: signature of adaptive evolution in cetacean mitochondrial tRNAs. *PLoS ONE* 11: e0158129.

Moran RC. 1983. *Equisetum x ferrissii* (Equisetaceae) in Illinois. *Castanea* 48:79–82.

Nanjappa D, Kooistra WH, Zingone A. 2013. A reappraisal of the genus *Leptocylindrus* (Bacillariophyta), with the addition of three species and the erection of *Tenuicylindrus* gen. nov. *J Phycol* 49:917–936.

Posada D, Buckley TR. 2004. Model selection and model averaging in phylogenetics: advantages of Akaike Information Criterion and Bayesian approaches over likelihood ratio tests. *Syst Biol* 53:793-808

Quandt D, Stech M. 2004. Molecular evolution of the *trnT*_{UGU}–*trnF*_{GAA} region in bryophytes. *Plant Biol (Stuttg)* 6:545–554.

Quandt D, Stech M. 2005. Molecular evolution of the *trnL*_{UAA} intron in bryophytes. *Mol Phylogenet Evol* 36:429–443.

Quandt D, Müller K, Stech M, Frahm JP, Frey W, Hilu KW, Borsch T. 2004. Molecular evolution of the chloroplast *trnL*-*UAA*-*F* region in land plants. *Monogr Syst Bot Mo Bot Gard* 98:13–37.

Renzaglia KS, Dengate SB, Schmitt SJ, Duckett JG. 2002. Novel features of *Equisetum arvense* spermatozoids: insights into pteridophyte evolution. *New Phytol* 154:159–174.

Ruhl MW, Wolf M, Jenkins TM. 2010. Compensatory base changes illuminate morphologically difficult taxonomy. *Mol Phylogenet Evol* 54:664–669.

Simon D, Fewer D, Friedl T, Bhattacharya D. 2003. Phylogeny and self-splicing ability of the plastid tRNA-Leu group I intron. *J Mol Evol* 57:710–720.

Stech M, Quandt D, Frey W. 2003. Molecular circumscription of the hornworts (Anthocerotophyta) based on the chloroplast DNA *trnL-*UAA-trnF** region. *J Plant Res* 116:389–398.

Taberlet P, Gielly L, Pautou G, Bouvet J. 1991. Universal primers for amplification of three non-coding chloroplast regions. *Plant Mol Biol* 17:1105–1109.

Vogel JC, Russell SJ, Rumsey FJ, Barrett JA, Gibby M. 1998. Evidence for maternal transmission of chloroplast DNA in the genus *Asplenium* (Aspleniaceae, Pteridophyta). *Bot Acta* 111:247–249.

Won H, Renner SS. 2005. The chloroplast *trnT-trnF* region in the seed plant lineage Gnetales. *J Mol Evol* 61:425–436.

Zapelloni F, Jurado-Rivera JA, Jaume D, Juan C, Pons J. 2021. Comparative mitogenomics in *Hyalella* (Amphipoda: Crustacea). *Genes (Basel)* 12:292.

Zuker M. 2003. Mfold web server for nucleic acid folding and hybridization prediction. *Nucleic Acids Res* 31:3406–3415.

Appendix 1

Equisetum sequences used in this study are listed by subgenus and then by specimen (and Genbank accession number). Sequences marked with an asterisk (*) were generated by the author. All other sequences were downloaded from GenBank. For further information, please consult the sequence data and description recorded in GenBank.

subg. Equisetum

Eq_arvensel1 (OQ971732*), Eq_arvensel2 (OQ971739*), Eq_arvensel3 (AY226125), Eq_arvensel4 (JN968380), Eq_arvensel5 (LT606678), Eq_arvensel6 (LT606680), Eq_arvensel7 (LT606681), Eq_diffusum1 (AY226126), Eq_diffusum2 (MH750050), Eq_fluviatile1 (GQ244922), Eq_fluviatile2 (AY226121), Eq_palustrel1 (GQ244925), Eq_palustrel2 (AY226123), Eq_palustrel3 (MH750072), Eq_pratensel1 (GQ244926), Eq_pratensel2 (AY226122), Eq_pratensel3 (MH750073), Eq_pratensel4 (MH750074), Eq_sylvaticum1 (OQ971735*), Eq_sylvaticum2 (AY226120), Eq_sylvaticum3 (GQ24492), Eq_sylvaticum4

(MH750083), Eq_telmateia1 (OQ971738*), Eq_telmateia2 (OQ971741*), Eq_telmateia3 (AY226119), Eq_telmateia4 (MH750087)

subg. Hippochaete

Eq_giganteum1 (AY226118), Eq_giganteum2 (MH750058),
 Eq_giganteum3 (MH750057), Eq_giganteum4 (MH750056),
 Eq_giganteum5 (MH750055), Eq_hyemale1 (OQ971731*),
 Eq_hyemale2 (AY226110), Eq_hyemale3 (AY327837), Eq_hyemale4 (GQ244923),
 Eq_hyemale5 (MH750062), Eq_hyemale6 (MH750063),
 Eq_laevigatum1 (OQ971737*), Eq_laevigatum2 (AY226112),
 Eq_myriochaetum1 (OQ971736*), Eq_myriochaetum2 (AY226114),
 Eq_myriochaetum3 (MH750066), Eq_myriochaetum4 (MH750067),
 Eq_praealtum1 (MH750059), Eq_praealtum2 (MH750060),
 Eq_ramosissimum1 (OQ971740*), Eq_ramosissimum2 (AY226115),
 Eq_ramosissimum3 (ON641349), Eq_ramosissimum4 (MW074919),
 Eq_ramosissimum5 (MH750078), Eq_scirpoides1 (OQ971743*),
 Eq_scirpoides2 (AF182359), Eq_scirpoides3 (AY226116),
 Eq_scirpoides4 (GQ244927), Eq_variegatum1 (OQ971734*),
 Eq_variegatum2 (OQ971744*), Eq_variegatum3 (MH750098),
 Eq_variegatum4 (MH750097), Eq_variegatum5 (GQ244929),
 Eq_variegatum6 (MH750093), Eq_variegatum7 (MH750096),
 Eq_xylochaetum1 (MH750107), Eq_xylochaetum2 (NC_065985),
 Eq_x_ferrissii1 (OQ971737*), Eq_x_ferrissii2 (AY226111)

subg. Paramochaete

Eq_bogotense1 (OQ971733*), Eq_bogotense2 (MH750045),
 Eq_bogotense3 (MH750046), Eq_bogotense4 (AY226124)

Comparing Self-Efficacy and Grades of Students in Progressive Accounting Course Levels

Jefferson T. Davis

Weber State University

ABSTRACT

Self-efficacy has a long, rich research history and is defined as an individual's judgment of their own capabilities to perform an action. In other words, "How confident am I that I can do well on this test, in this sporting event, in this game, on this assignment, or in this course?" Confidence in one's abilities is an important aspect of success. Confidence usually increases as one increases their preparation, experience, and history of success. Confidence in an action usually has a positive relationship with how well a person enjoys doing the specific action. On the other hand, as an individual learns more and has more experience in a particular task, they also become more aware of the complexities, difficulties, and challenges of completing that task successfully. Thus, the more one knows, the more they may realize how much more they need to learn, develop, and apply to continue to have success. This study measures and compares self-reported answers to 10 self-efficacy questions for new, intermediate, and advanced accounting students. The research reports self-efficacy differences in the course levels of the students. It also studies whether higher self-efficacy has a positive relationship with higher grades, as has been reported by some

prior research, but does not find much predictability of course grades using student self-reported self-efficacy levels.

Introduction

Bandura (1977, 1986, 1997) first contributed a seminal article and continued research and theories related to self-efficacy (SE) (see also Schwarzer 1992). Mayer et al. (2004) discussed their theory and findings related to emotional intelligence (EI). Gagne and Deci (2005) presented self-determination (SD) theory that includes the concepts of intrinsic and extrinsic motivation. Pintrich and Degroot (1990) and Pintrich and Schrauben (1992) provided important theories on self-regulated learning (SRL) and learning strategies. Using these psychology research articles as a foundation, subsequent researchers have studied academic performance and procrastination as it relates to these important psychological constructs in students (see, e.g., Haycock et al. 1998; Deniz et al. 2009; Barrows et al. 2013; Hen and Goroshit 2014a, b).

The basic research model for this research in general is presented in Figure 1. The interaction of self-efficacy, emotional intelligence, self-determination, and self-regulated learning, all combine to affect procrastination and performance. Thus, higher self-efficacy, higher emotional intelligence, higher self-determination, and better self-regulated learning applied by an individual lead to less procrastination and better performance.

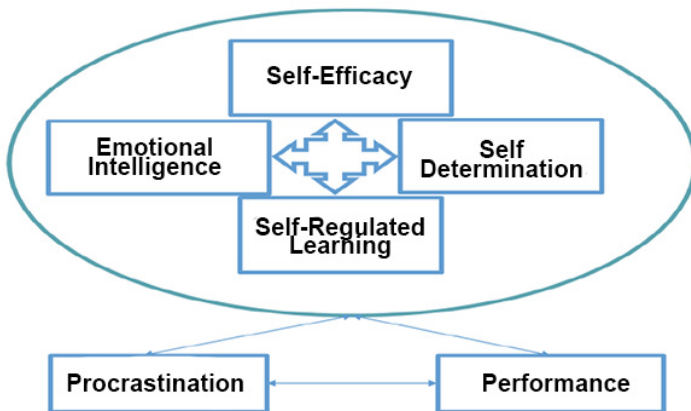


Figure 1: Cognitive constructs, procrastination, and performance

Specifically, Hen and Goroshit (2014b) found statistically significant results showing that SE as a mediating variable of emotional intelligence had a positive indirect relationship with improved grade point average (GPA) and an inverse indirect relationship with procrastination. However, they also found that a direct relationship between SE and GPA and with procrastination was not statistically significant. Their study used structural equation modeling. One recent academic study of accounting students found a small positive relationship between student self-reported levels of these cognitive constructs and better scores on a practice audit section of the certified public accountant exam (Davis 2021). Unlike Hen and Goroshit (2014b), Davis (2021) used simpler statistical descriptive and predictive models than structural equation modeling and did not try to separate out mediating or moderating variables. In summary, most of the research has found limited or mixed results as to the positive effect of these cognitive constructs on performance in terms of grades.

Davis (2021) also suggested broadening the research by using more than just students from one class level to measure whether levels of SE, EI, SD, and SRL were different for different student groups based on class level and how this might relate to academic success. The current research study takes up this task to add to this literature stream by isolating one of these cognitive constructs, SE, from the overall research model and comparing progressive course level student groups' self-assessment levels of SE. The basic research question is whether self-reported SE levels of students in higher course levels are higher than self-reported SE levels by students in lower course levels. After assessing SE levels of students in progressive course levels, the research then examined whether academic success can be predicted based on SE and course level. The current research model is presented in Figure 2.

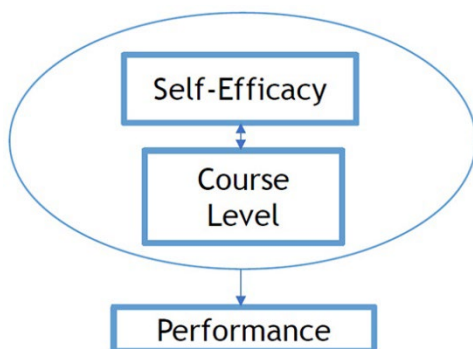


Figure 2: Self-efficacy, course level, and performance.

Bandura (1977, 1986, 1997) suggests that individuals with high levels of SE imagine how they can succeed and trust in their own abilities. Pajares (2016) explains four sources of SE in his summary of current directions in SE research. The first source has a stronger impact on SE than the last three sources. The first source is an individual's interpretive results of their performance. Simply put, outcomes interpreted as successful increase SE, whereas outcomes believed to be failures will decrease SE. The second source of SE beliefs is what the individual perceives are the results of the actions of those around them such as their peers. When people lack experience or knowledge, they tend to be more sensitive to the outcomes of other people's success and failures, which then affects their own SE beliefs as they compare themselves with others. The third source of SE beliefs comes from the verbal persuasions of others. Positive and negative reinforcement has an impact on an individual's SE. And fourth, physiological and emotional states (stress, fatigue, mood) also provide information about SE beliefs. Positive thinking techniques can transfer into the classroom and help students excel in academic achievement as well. Students who perceive themselves as being competent will more likely strive to learn how to do better on challenging tasks such as exams. Those with high levels of SE show lower levels of test anxiety, possibly because they believe in themselves and are able to imagine a successful outcome (Barrows et al. 2013). The general notion is also proposed that SE improves as one gains experience and knowledge. However, higher SE may be dampened as more experience and knowledge increases the individual's awareness of complexities and challenges of successfully completing tasks that are more difficult as one encounters more advanced concepts and applications. Also, higher-level courses also include colleagues and competitors who have high levels of knowledge and ability. It is also possible that there could be overconfidence, such as the 'know-it-all syndrome,' in which an individual's lack of experience does not allow the individual to fully comprehend the scope, competition, and complexity of the task at hand. In summary, a person's selection, integration, interpretation, and recollection of these various sources of information influence the judgments of SE (Pajares 2016).

Definitions, Survey Sources, Questions, and Hypotheses

Self-efficacy is described as an individual's judgments of his or her capabilities to perform given actions (Schwarzer 1992). SE can also be thought of as the confidence a person has in themselves and their abilities to perform a given action. For example, a student with high SE is confident in his or her ability to perform well on tests. If a student does

not believe they have a strong ability to perform well on tests, this would be an indication of low SE on test taking.

Schwarzer and Jerusalem (1995) developed a generalized SE scale that provides the source of the 10 survey questions for the current study. A Likert scale of 1 to 5 (low to high) was used in the current study. The survey was administered online through the learning management system at an accredited accounting program.¹ The students were offered the SE survey as an extra credit option to each course. Because the survey is a self-assessment survey, there is no grade and no right or wrong answers for the survey. The survey instructions made this clear to the students. The results of the survey were not reviewed nor summarized until after the semester grades were posted. Only the extra credit points relating to 2% of the total course grade were recorded for students who chose to take the survey.

The survey was offered to students in five different courses that included beginning courses all the way to a master's level course. The beginning financial accounting class (2010) had 46 student respondents, the beginning managerial class (2020) had 111 respondents, the accounting information systems class (3750) had 133 respondents, the senior-level auditing class (4510) had 56 respondents, and the graduate accounting information systems class had 30 respondents. All classes included multiple semesters except the auditing class, which comprised students all from one semester. These classes were all taught by the same instructor. The specific questions are included in the results.

Hypothesis 1 states that students in higher-level courses will have higher average levels of self-reported SE than those in lower-level courses. In other words, it is expected that as students progress through their academic careers, their self-reported SE levels will increase. Hypothesis 2 states that the course grade is higher for students that self-reported higher levels of SE than for students who self-reported lower levels of SE. In other words, there is a positive relationship between higher levels of SE and grade performance.

Research Approach and Results for Hypothesis 1

To test Hypothesis 1, the overall average of all 10 question responses was calculated for each class group. The average for each of the 10 SE questions was also calculated for each class group. An overall ANOVA was performed for the overall average SE questions as well as each of the 10 SE questions to discover any statistical differences by class group. Finally, paired t-tests were performed for the overall average

¹ Accreditation by the Association to Advance Collegiate Schools of Business.

for all 10 questions and for each of the 10 questions. Table 1 shows the number of responses and average scores for the SE questions for all students and then for each course level. The highest course average for each SE question is shown in boldface text.

Table 1: Average SE Question Responses						
Self-efficacy question	Average response score by course level					
	All courses	2010	2020	3750	4510	6610
Response count	371	44	109	132	56	30
Average all 10 questions	3.960	4.033	4.029	3.886	3.936	3.960
Q1: I can always manage to solve difficult problems if I try hard enough	4.208	4.273	4.220	4.136	4.214	4.367
Q2: If someone opposes me, I can find the means and ways to get what I want.	3.367	3.318	3.505	3.326	3.286	3.267
Q3: It is easy for me to stick to my aims and accomplish my goals.	3.884	3.955	3.844	3.879	3.946	3.833
Q4: I am confident that I could deal efficiently with unexpected events.	3.981	4.068	4.147	3.841	3.946	3.933
Q5: Thanks to my resourcefulness, I know how to handle unforeseen situations.	3.889	3.909	4.009	3.788	3.839	3.967
Q6: I can solve most problems if I invest the necessary effort.	4.423	4.591	4.422	4.379	4.393	4.433
Q7: I can remain calm when facing difficulties because I can rely on my coping abilities.	3.782	3.841	3.844	3.689	3.732	3.967
Q8: When I am confronted with a problem, I can usually find several solutions.	3.836	4.023	3.908	3.742	3.804	3.767
Q9: If I am in trouble, I can usually think of a solution.	4.054	4.182	4.183	3.977	3.982	3.867
Q10: I can usually handle whatever comes my way.	4.148	4.182	4.239	4.023	4.214	4.200

Response scale: 1 to 5 (Low to High)

Figure 3 provides a graphical comparison of the course averages of these same SE responses.

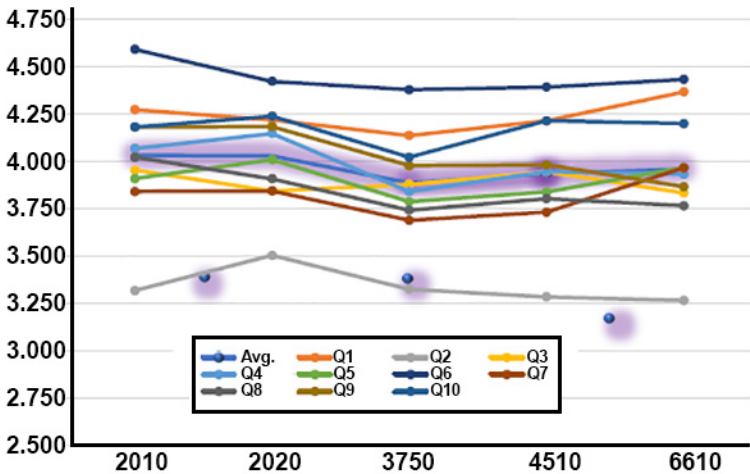


Figure 3: Self-efficacy question response averages by course level. Average highlighted in purple shadow.

The graph shows that the average response for question 6 is higher than those of all other questions. Question 6 refers to effort, and the responses indicate strong SE in relation to effort and success in a task. Question 6 is a similar question to question 1. Questions 1 and 6 are worded slightly differently, but they come in as highest and second highest responses for overall average and the averages for each class group generally. The similarity of the questions and their results suggest consistency in the answers among the students overall, which lends support to internal validity of students reading the questions and responding appropriately to what they understand the question to mean. This also suggests that students took the survey questions seriously.

The graph also highlights that question 2 has a much lower response score in terms of SE than the other questions. Question 2 refers to opposition and shows that students in general do not feel confident in handling opposition.

The graph highlights a general pattern that there is a dip in the SE response levels for the 3750 group, a junior-level course. The beginning courses generally have the highest level of SE whereas the middle-level course generally has the lowest level of SE, and the senior- and graduate-level courses again show a higher level of SE but do not reach the level

of the beginning course SE levels. The 2010 class has the highest overall average response at 4.033, and the 2020 class has the second highest average response at 4.029. The 3750 class has the lowest overall average response at 3.866, while the 4510 and 6610 classes recover with averages of 3.936 and 3.960, respectively.

For the individual question responses, the 2010 class has 3 of the 10 highest question averages (questions 3, 6, 8) while the 2020 class has 5 of the 10 highest question averages (questions 2, 4, 5, 9, 10). The master's class, 6610, has the 2 other highest average responses, for questions 1 and 7. It is interesting to note that the 6610 class also has 2 of the lowest responses (questions 3 and 9). The 3750 and 4510 classes do not have any of the highest averages for any of the individual questions. The 3750 class also ranks lowest in 7 of the 10 questions.

Table 2 shows further analysis of the survey questions results by class. The ANOVA p-value is given for the questions overall (0.132), which is not significant at the 90% confidence level to support differences in the class groups' responses overall. However, some group differences were found using ANOVA for individual questions 4, and 9. None of the other individual questions had ANOVA results that were statistically significant.

Table 2: Question responses rank, ANOVA, paired T-test results							
Self Efficacy Average all 10 questions							
ANOVA P-value	0.132						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)							
	2010	2020	3750	4510	6610	Avg Response	Rank of Average
2010	1.000					4.033	1 Highest Rank
2020	0.483	1.000				4.029	2
3750	0.044	0.011	1.000			3.866	5 Lowest Rank
4510	0.144	0.093	0.218	1.000		3.936	4
6610	0.259	0.238	0.211	0.401	1.000	3.960	3
Self Efficacy Q1: I can always manage to solve difficult problems if I try hard enough							
ANOVA P-value	0.346						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)							
	2010	2020	3750	4510	6610	Avg Response	Rank of Average
2010	1.000					4.273	2
2020	0.320	1.000				4.220	3
3750	0.105	0.148	1.000			4.136	5 Lowest Rank
4510	0.476	0.476	0.207	1.000		4.214	4
6610	0.236	0.090	0.015	0.104	1.000	4.367	1 Highest Rank
Self Efficacy Q2: If someone opposes me, I can find the means and ways to get what I want.							
ANOVA P-value	0.164						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)							
	2010	2020	3750	4510	6610	Avg Response	Rank of Average
2010	1.000					3.318	3
2020	0.099	1.000				3.505	1 Highest Rank
3750	0.478	0.022	1.000			3.326	2
4510	0.417	0.030	0.352	1.000		3.286	4
6610	0.377	0.034	0.310	0.446	1.000	3.267	5 Lowest Rank

Comparing Self-Efficacy and Grades in Accounting Courses 151

Self Efficacy Q3: It is easy for me to stick to my aims and accomplish my goals.							
ANOVA P-value	0.870						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)	2010	2020	3750	4510	6610	Avg Response	Rank of Average
	2010	1.000				3.955	1 Highest Rank
	2020	0.204	1.000			3.844	4
	3750	0.284	0.362	1.000		3.879	3
	4510	0.477	0.173	0.265	1.000	3.946	2
	6610	0.255	0.474	0.389	0.250	1.000	3.833 5 Lowest Rank
Self Efficacy Q4: I am confident that I could deal efficiently with unexpected events.							
ANOVA P-value	0.055						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)	2010	2020	3750	4510	6610	Avg Response	Rank of Average
	2010	1.000				4.068	2
	2020	0.274	1.000			4.147	1 Highest Rank
	3750	0.037	0.002	1.000		3.841	5 Lowest Rank
	4510	0.218	0.076	0.217	1.000	3.946	3
	6610	0.233	0.108	0.291	0.473	1.000	3.933 4
Self Efficacy Q5: Thanks to my resourcefulness, I know how to handle unforeseen situations.							
ANOVA P-value	0.171						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)	2010	2020	3750	4510	6610	Avg Response	Rank of Average
	2010	1.000				3.909	3
	2020	0.243	1.000			4.009	1 Highest Rank
	3750	0.192	0.007	1.000		3.788	5 Lowest Rank
	4510	0.329	0.074	0.323	1.000	3.839	4
	6610	0.371	0.381	0.097	0.206	1.000	3.967 2
Self Efficacy Q6: I can solve most problems if I invest the necessary effort.							
ANOVA P-value	0.433						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)	2010	2020	3750	4510	6610	Avg Response	Rank of Average
	2010	1.000				4.591	1 Highest Rank
	2020	0.069	1.000			4.422	3
	3750	0.029	0.306	1.000		4.379	5 Lowest Rank
	4510	0.055	0.387	0.443	1.000	4.393	4
	6610	0.132	0.463	0.324	0.379	1.000	4.433 2
Self Efficacy Q7: I can remain calm when facing difficulties because I can rely on my coping abilities.							
ANOVA P-value	0.420						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)	2010	2020	3750	4510	6610	Avg Response	Rank of Average
	2010	1.000				3.841	3
	2020	0.492	1.000			3.844	2
	3750	0.170	0.082	1.000		3.689	5 Lowest Rank
	4510	0.271	0.209	0.377	1.000	3.732	4
	6610	0.262	0.225	0.044	0.098	1.000	3.967 1 Highest Rank
Self Efficacy Q8: When I am confronted with a problem, I can usually find several solutions.							
ANOVA P-value	0.198						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)	2010	2020	3750	4510	6610	Avg Response	Rank of Average
	2010	1.000				4.023	1 Highest Rank
	2020	0.234	1.000			3.908	2
	3750	0.032	0.046	1.000		3.742	5 Lowest Rank
	4510	0.096	0.202	0.295	1.000	3.804	3
	6610	0.084	0.170	0.430	0.408	1.000	3.767 4
Self Efficacy Q9: If I am in trouble, I can usually think of a solution.							
ANOVA P-value	0.057						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)	2010	2020	3750	4510	6610	Avg Response	Rank of Average
	2010	1.000				4.182	2
	2020	0.495	1.000			4.183	1 Highest Rank
	3750	0.082	0.012	1.000		3.977	4
	4510	0.101	0.029	0.481	1.000	3.982	3
	6610	0.043	0.014	0.215	0.221	1.000	3.867 5 Lowest Rank
Self Efficacy Q10: I can usually handle whatever comes my way.							
ANOVA P-value	0.119						
T-test: 2 sample unequal variance one-tail p-values Significant to 10 (Column Group has higher response value)	2010	2020	3750	4510	6610	Avg Response	Rank of Average
	2010	1.000				4.182	4
	2020	0.335	1.000			4.239	1 Highest Rank
	3750	0.108	0.007	1.000		4.023	5 Lowest Rank
	4510	0.409	0.411	0.030	1.000	4.214	3
	6610	0.455	0.384	0.081	0.459	1.000	4.200 2

The 2-sample unequal paired t-test for the average overall responses between the groups was consistent with the results found in the group averages. The 3750 class average was significantly lower than those of the 2010 and 2020 classes. The 4510 group average was also significantly lower than the 2020 class average. Table 2 also shows fairly consistent t-test statistical differences for most of the individual questions between beginning classes (2010 and 2020) and the 3750 class. The 2-sample unequal paired t-test resulting in significant difference for

class 6610 in relation to class 3750 for questions 1 and 7 was also consistent in that the 6610 class had the lowest response for questions 1 and 7.

Research Approach and Results for Hypothesis 2

A multiple regression using the individual SE responses from all students was used to predict grades. The independent variables were the 10 question responses from each of the students. The dependent variable was the class percentage grade of each student. The regression results are found in Table 3.

Table 3: Self Efficacy and Student Performance

Predicting Student Grades Using Self Efficacy Student Responses										
Multiple Regression of all 10 questions to Grade % All Course Levels										
Regression Statistics										
Multiple R	0.267									
R Square	0.071									
Adjusted R Square	0.045 Adj R square better than regression for Average Self Efficacy which was negative									
Standard Error	12.47									
Observations	371									
ANOVA										
	df	SS	MS	F	Significance F					
Regression	10	4291.2	429.1	2.762	0.0027	Significant				
Residual	360	55940	155.4							
Total	370	60231								
Single Regress to Grade										
	Coefficient	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%	F-Test P-Value	Adj R Sq
Intercept	77.796	6.075	12.806	0.000	65.849	89.743	65.849	89.743		
Q1: I can always manage to solve difficult problems if I try hard enough.	0.030	1.323	2.291	0.023	0.429	5.631	0.429	5.631	0.010	0.02
Q2: If someone opposes me, I can find the means and ways to get what I want.	-0.370	1.044	-0.354	0.723	-2.423	1.684	-2.423	1.684		
Q3: It is easy for me to stick to my aims and accomplish my goals.	1.237	0.989	1.251	0.212	-0.708	3.182	-0.708	3.182		
Q4: I am confident that I could deal efficiently with unexpected events.	-2.155	1.066	-2.022	0.044	-4.251	-0.058	-4.251	-0.058	0.312	0.00
Q5: Thanks to my resourcefulness, I know how to handle unforeseen situations.	-0.157	1.174	-0.134	0.894	-2.466	2.152	-2.466	2.152		
Q6: I can solve most problems if I invest the necessary effort.	0.766	1.240	0.618	0.537	-1.672	3.204	-1.672	3.204		
Q7: I can remain calm when facing difficulties because I can rely on my coping abilities.	-1.276	0.949	-1.344	0.180	-3.143	0.591	-3.143	0.591		
Q8: When I am confronted with a problem, I can usually find several solutions.	0.995	1.091	0.912	0.362	-1.150	3.141	-1.150	3.141		
Q9: If I am in trouble, I can usually think of a solution.	-3.030	1.190	-2.540	0.011	-5.370	-0.691	-5.370	-0.691	0.393	0.00
Q10: I can usually handle whatever comes my way.	4.049	1.268	3.193	0.002	1.555	6.542	1.555	6.542	0.046	0.00

The overall F-test is statistically significant at 0.0027. However, the adjusted R-Square value is only 0.045, which indicates the model has very little explanatory ability. Note that the independent variable coefficients are split as to negative and positive signs, showing collinearity among the independent variables. Single regressions were also performed for each of the 10 questions individually, and only questions 1 and 10 had significant F-test p-values. However, again the adjusted R-square values were extremely small in these cases.

Conclusions, Thoughts, and Further Research

SE as a measure of “confidence” is an important cognitive construct related to student performance. The current study adds to the literature by comparing student responses to SE questions by progressive

class groups. This preliminary study found that there are differences in SE levels from self-response survey questions at progressive course levels. The expectation was that SE levels of students would increase in relation to higher levels of student groups in a college setting. However, the results found that beginning students generally had the highest SE levels. Then there was a dip in the SE levels for intermediate or junior-level students, followed by an increase in SE levels for senior and graduate students. However, senior and graduate student SE levels were still lower than those of beginning students. The results suggest a potential overconfidence of beginning college students. One might expect this for a first beginning college accounting class (2010). However, the same was true for the second beginning accounting class (2020). It seems that students' SE levels take a hit during some intermediate courses, before increasing and leveling out a bit at senior and graduate levels.

The results lead educators and researchers to ask, "Do students really understand their own SE? And, if they do, can they apply their SE or confidence well enough to improve their course grades, or maybe more specifically test grades?" Cognitive learning is a very complicated process with many confounding variables. The results of this study suggest a possible 'teenage syndrome,' in which younger or new students think they know everything. More experience in school potentially leads to a more conservative view of ones' own abilities. Perhaps more experience in school increases the student's humility. Perhaps the student becomes more teachable and becomes more aware of the complexities and challenges of increasing higher-level tasks. Students progressing through higher college course levels face more obstacles or 'opposition' as alluded to in question 2 of the SE questions. Higher-level courses include more advanced concepts and applications, in addition to increased knowledge and abilities of fellow students as colleagues and competitors. And finally, can students get 'worn down' physiologically and emotionally as they progress through college course levels?

The main limitation of the current study is the scope. A study on SE in relation to course levels and performance would benefit from more students and an assortment of different courses, topics, and instructors. A study that extends to professionals in addition to students would also be a valuable comparison of SE levels. Also, is there a way to measure SE rather than survey questions?

Another potential limitation of the current study is that course grade was used as a proxy for student success. Prior research that found evidence of SE (and some other cognitive constructs) as a positive predictor of student success used single test scores (e.g., Barrows et al. 2013 and Davis 2021) rather than overall course grade. Overall course

grade likely has more confounding variables than single test scores. A limitation of this study may have to do with the SE questions themselves. The 10 questions have some overlapping similarities in meaning, so some further parsing of questions that are similar in meaning may be useful. These similar meanings in the questions showed up in the results of Hypothesis 2. The multiple regression for predicting grades based on the SE questions as independent variables resulted in positive and negative coefficients indicating collinearity in the independent variables. That means the questions for SE are not independent as required by linear regression theory. Further testing in which the variables are evaluated and eliminated if there are covariance issues is needed. Some other method of prediction such as neural network modeling where analysis is based on nonlinear and nonparametric statistical inference may be more suitable.

References

- Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioural change. *Psychological Review*, 84: 191-215.
- Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.
- Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*. New York: Freeman.
- Barrows, J., Dunn, S., & Lloyd, C. (2013) Anxiety, self-efficacy, and college exam grades. *Universal Journal of Educational Research*, 1(3): 204-208.
- Davis, J. (2021). Self-efficacy, emotional intelligence, self-determination, and self-regulated learning: student survey results and relationship to practice CPA exam scores in an auditing course. *Journal of the Utah Academy of Sciences, Arts, & Letters*, 98: 61-78.
- Deniz, M., Tras, Z., & Adygan, D. (2009). An investigation of academic procrastination, locus of control, and emotional intelligence. *Educational Sciences: Theory & Practice*, 9(2): 623-632.
- Gagne, M., & Deci, E. (2005) Self-determination theory and work motivation. *Journal of Organizational Behavior*, 26: 331-362.

Haycock, L., McCarthy, P., & Skay, C. (1998). Procrastination in college students: the role of self-efficacy and anxiety. *Journal of Counseling & Development*, 76(3): 317-324.

Hen, M., & Goroshit, M. (2014a). Academic self-efficacy, emotional intelligence, gpa and academic procrastination in higher education. *Eurasian Journal of Social Science*, 2(1): 1-10.

Hen, M., & Goroshit, M. (2014b). Academic procrastination, emotional intelligence, academic self-efficacy, and GPA: a comparison between students with and without learning disabilities. *Journal of Learning and Disability*, 47(2): 116-124.)

Mayer, J., Salovey, P., & Caruso, D. (2004). Emotional intelligence: theory, findings, and implications. *Psychological Inquiry*, 60: 197-2015.

Pajares, F. (2016). *Current Directions in Self-Efficacy Research*. Retrieved November 15, 2023, from <https://www.dynaread.com/current-directions-in-self-efficacy-research>.

Pintrich, P., & DeGroot, E. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, 82: 33-40.

Pintrich, P., & Schrauben, B. (1992). Students' motivational beliefs and their cognitive engagement in classroom academic tasks. In D. Schunk & J. Meece (Eds.), *Student Perceptions in the Classroom: Causes and Consequences*, pp. 149-183. Hillsdale, NJ: Erlbaum.

Schwarzer, R. (1992). *Self-Efficacy: Thought Control of Action*. Washington, DC: Hemisphere.

Schwarzer, R., & Jerusalem, M. (1995). Generalized self-efficacy scale. In J. Weinman, S. Wright, & M. Johnston (Eds.), *Measures in Health Psychology: A User's Portfolio, Causal and Control Beliefs* (pp. 35-37). Windsor, UK: NFER-Nelson.

Social Studies, Culture, and the Utah DLI Program: A Preliminary *Didaktik* Analysis

**William J. Davis, Jiazhen Yan, Ruohan Gao, and Ziyao
Zhou**

Southern Utah University

Abstract

The purpose of this case study was to examine Utah's Grades 1-6 social studies standards and the instructional resources provided by the state for Chinese Dual Language Immersion (DLI) teachers to investigate how social studies instruction supported cultural learning for DLI students. A collaborative, Didaktik analysis of the standards and resources found that, in Grades 1-3 and 6, during which the partner-language DLI teacher is responsible for social studies, Chinese cultural knowledge or learning was not explicitly emphasized within the instructional resources provided in Grades 1-3. The one possible example found was in Grade 6, which included extensive materials for lessons on ancient Chinese civilization and culture. Despite this well-developed set of resources, it was unclear whether ancient China constituted a topic unique to the Chinese DLI program social studies classes or if this was a topic that might be learned by both DLI and non-DLI students across the state. Available resources explicitly encourage Chinese DLI teachers to teach American and Utah cultural traditions, but not necessarily the partner language's cultural traditions. The lack of focus on partner-language

culture raises questions for both second language learning in DLI settings and DLI teacher professional development.

“I think it is that to be a DLI teacher, maybe just bring more culture and things here. ‘Cause when we doing a teaching— ‘cause when I did teaching, ‘cause you’re a lot of the time limited...”

The quote above from An, a participant in a study on Chinese Dual Language Immersion (DLI) teacher professional learning and development initiated by the first and second author (see Yan & Davis, 2023), reflects what may be an ongoing concern both in DLI teaching and more broadly across bilingual education programs. Despite the importance An saw in cultural knowledge and the fact that Chinese people “have a different culture” than American students, finding time and opportunities to teach Chinese culture was a challenge. An’s comments in her interview reflect both the close relationship between culture and the language learning observed by second language educators and scholars (e.g., Jiang, 2000; Kim, 2019), as well as ongoing debates in how to integrate cultural and language learning in second language classes (e.g., Byrd, 2014; Kim, 2020). Among the challenges in teaching culture in DLI settings is the appearance of culture across teaching areas; students are expected to learn about culture during both second or additional language instruction (e.g., American Council on Teaching of Foreign Languages, 2023) and in social studies lessons (see National Council for the Social Studies, n.d.). The purpose of this study was to use a *Didaktik* analysis to explore how social studies in particular is used across several grade levels to support cultural learning for DLI students, using the case of Utah’s Chinese DLI program.

Conceptual Framework

The Utah DLI Program

Since 2009, Utah’s legislature has funded a statewide DLI program, which provides public school students in participating schools the opportunity to learn in both English and an approved partner language like Spanish, Portuguese, Russian, Chinese, French, or German (Sung & Tsai, 2019). Unlike two-way DLI programs, which serve both native English speakers and native speakers of the partner language (Li et al., 2016), Utah’s DLI program is primarily one-way; the program typically serves native English speakers as they learn the partner language (Sung

& Tsai, 2019). Participating schools begin establishing the partner language in a first-grade class, where two classes are shared by an English-language teacher and a partner-language teacher; in an arrangement known as the 50:50 DLI model, these teachers instruct each group for half of the day so students learn in both English and the partner language every day (Spicer-Escalante, 2017; Steele et al., 2019). The program is then extended throughout the elementary grade levels using this same 50:50 structure. Although elementary-level DLI teachers are primarily responsible for language and literacy instruction, they share content area teaching responsibilities with English-language teachers (Pascopella, 2013).

Social studies as a content area can be used to illustrate the division in responsibilities among DLI teachers. Each subject area is divided by the state into primary instruction and reinforcement responsibilities using prescribed percentages of instructional minutes (see Table 1) (Pascopella, 2013; Utah Dual Language Immersion, 2017). In grades 1-3, social studies instruction primarily is the responsibility of partner-language teachers. Social studies instruction is paired with science instruction in the partner language for 15% of instructional minutes; the English-language teacher is then responsible for reinforcing social studies, along with science and math, for 15% of instructional minutes. Responsibilities shift in grades 4-5, when social studies is taught by the English-language teacher across 8.5% of instructional minutes, which are shared with content area reinforcement. This shared allotment of time for social studies is in stark contrast to science, which accounts for 16.5% of instructional minutes in English. Of the four core content areas, far less time is allocated to social studies instruction, even when taking into account English-language and partner-language instruction together.

Content Area	Grade Levels	
	1-3	4-5
English Language Arts	35%	25%
Target language literacy	15%	25%
Math (English)	–	16.5%
Math in target language	20%	–
Math reinforcement in target language	–	8.5%
Math & content areas reinforcement (English)	15%	–
Social studies & content area reinforcement (English)	–	8.5%
Content areas in target language	15%	–
Science in target language	–	16.5%

Social studies is not restored as an independent subject until Grade 6, when partner-language teachers instruct DLI students in social studies (Utah Dual Language Immersion, 2017).

Teaching Culture in a Diminished/Declining Social Studies and Beyond

The standards of both the National Council for the Social Studies (n.d.) and the American Council on the Teaching of Foreign Languages (2023) highlight culture as a central area of focus; however, the focus on these areas among scholars of social studies and second language teaching appears markedly different. Concerns about the emphasis on language skills over culture in teacher preparation and licensure requirements (e.g., Byrd et al., 2011; Byrd, 2014; Kim, 2020) have played at least some part in the frequent calls by scholars for teacher professional learning and development related to cultural knowledge and teaching (Brameld 1957; Byrd et al., 2011; Byrd, 2014; Ivenz & Reid, 2022). Although some scholars have reported on cultural learning and teaching in the social studies (e.g., Brophy & Alleman, 2002; Brophy & Alleman, 2006; Schlein et al., 2016; Fui, 2019), these aspects of social studies education appear undertheorized and under-researched, perhaps a product of the decline in social studies teaching across the past 30 years.

The diminished focus on social studies as an elementary level subject is part of a long, ongoing curricular trend. Even before the ascendance of high-stakes testing and accountability brought about by the passage of the No Child Left Behind (NCLB) Act, the status of social studies as a school subject was labeled as “endangered” and “threatened” (Passe, 2006, p. 189; see also An, 2017). As NCLB brought about testing regimes in each state, including mandates for science instruction and testing across grades 3-5, non-tested subjects were negatively impacted by the new mandates (Au, 2009; O’Connor et al., 2007). Consequently, the social studies has seen a precipitous decline in instructional minutes, particularly in the elementary grades (Au, 2009; Demoiny, 2020; Heafner & Fitchett, 2012; O’Conner et al., 2007). Nevertheless, social studies teaching standards continue to call for robust instruction, including areas related to culture. For example, the standards from the National Council for the Social Studies (n.d.) identify culture as one of the curriculum’s ten themes, calling for “experiences that provide for the study of culture and cultural diversity.” Utah’s teaching standards for grades 1-6 all invoke culture, including specific standards related to various aspect of culture (e.g., Utah Education Network, n.d.). The reduced time allotted to elementary social studies may mean culture, to

the extent it is explicitly taught at all in elementary schools, must be taught as part of or alongside other subject areas.

Teaching culture is fraught with its own challenges, for both DLI and non-DLI teachers. Although scholars articulate close, if not intimate, relationships and importance between culture and language learning or teaching (Brameld, 1957; Hollins, 1996; Jiang, 2000; Kim, 2020), there is little consensus regarding what culture is and/or how to teach culture to K-12 students (Byrd, 2014; Jacobson, 1996). Different metaphors (e.g., Jiang, 2000) and conceptualizations or framings of culture (e.g., Jacobson, 1996; Kim, 2020) have contributed to various definitions of culture, as well as a multitude of ways to approach the subject in educational settings. These definitions or framings adopt different names and descriptions, including cultural competence (e.g., Ukpokodu, 2011), culturally relevant pedagogy (e.g., Ladson-Billings, 1995), and intercultural communication or competence (e.g., Ivenz & Reid, 2022; Kim, 2020, among others. Hollins (1996) framed the teaching of culture using different forms of curriculum. Whereas culture could be explicitly taught such as Banks's (1995) multicultural education or Hirsch's (1988) essentialist cultural literacy, culture is also implicitly conveyed through socialization and transmission occurring through textbooks and resources and school routines (Hollins, 1996). Cultural knowledge and teaching culture are viewed by many scholars as important in schools, yet what this body of knowledge is and how it should be taught remains contested and fractured in the literature.

Perhaps the most fundamental challenge affecting the teaching of culture is the absence of true immersion in the target culture, which may lead to the formation of what has been called a *third culture*. The term third culture might refer to individuals who are "caught between cultures" (Colantonio-Yurko et al., 2023, p. 53), as may be the case with the children of missionaries or military personnel living away from their home countries (Colantonio-Yurko et al., 2023; see also Moore & Barker, 2012). Third culture has also been used to describe contested spaces between groups of differing expertise, as Snow (1964) used the term to describe a third culture of scientists who directly shared their work with everyday people. In language education, third culture has been theorized as a space—sometimes a physical place, but in other cases conceptual—between a first language and culture and a second language and culture (Kramsch, 2009). Although a second language learner in a classroom setting is never fully immersed in the target culture, cultures, as Peterson and Coltrane (2003) note, are also never monolithic; a culture cannot be presented nor learned as a singular, homogenous body of information and interactions. This view of a third culture in language classrooms has existed for at least 30 years (see Kramsch, 1993), yet a

similar construct or theorization of learning may not exist in the social studies to aid in the teaching of culture.

Didaktik, Powerful Knowledge, and the Teaching of Culture

Whether the teaching of culture results in students' development of powerful knowledge is a largely unexplored topic. Whereas disciplinary knowledge constitutes specialized knowledge that has been verified in "robust and generally agreed-upon" ways (Young & Muller, 2013, p. 236), Deng (2021) has described powerful knowledge in terms of transformations; knowledge is powerful when it is transformed "into educational purposes...in ways that are conducive to the development of human powers" (p. 1654). Deng (2021) links such transformations to *Bildung*-centered *Didaktik*, a theoretical perspective on curriculum that seeks to unite "the acquisition of knowledge" with "the development of human potential" (p. 1654). In *Didaktik* analysis, there is a shift from questions concerning what students should know—a focus attributed to Anglo-Saxon curriculum analysis—to questions like, "What should [learners] become?" or "How should they become?" (Hamilton & Gudmundsdottir, 1994, p. 348). A *Didaktik* analysis examines both content and method, with a focus on changes to learners' development or potential. *Didaktik* theory can also be used analyze curriculum from a macro perspective (Werler & Tahirsylaj, 2022). In this study, a *Didaktik* approach is utilized to examine the following question: What do Utah's grades 1-6 social studies standards and provided instructional resources contribute to the development and cultural learning of a Chinese DLI student?

Methods

Study Context

The case study reported in this paper focuses on Utah's DLI program, with a particular focus on the supports provided for Chinese-language teachers. The research team decided to focus on the supports provided to Chinese DLI teachers for social studies instruction because of the team's respective connections to this program; the first and second author had been studying teacher professional learning and professional development in a Chinese DLI program (e.g., Davis & Yan, 2023; Yan & Davis, 2023), and all authors were involved as university supervisors or student teachers in DLI classrooms. This study targeted the social studies curriculum and supports provided to Chinese DLI teachers

between grades 1-6, which were the grades with which the research team had direct experience through student teaching.

Reflexivity Statement

As a result of the research experiences of the first and second authors, steps were taken as part of this study to interrogate beliefs and experiences related to cultural learning in Chinese DLI programs. Prior to student teaching, the first and second author had engaged in “kitchen sink reflexivity” across their research and instructor/teaching assistant work. Folkes (2022) described “kitchen sink reflexivity” as situations “where everyday talk with other researchers is used as a tool to interrogate positionalities” (p. 4). By the time this study was designed, the first and second author had come to see the teaching of culture as a challenge for Chinese DLI teachers. To enhance and expand their understanding of Chinese DLI teacher learning and development and the teaching of culture, two additional team members were enlisted as researchers, neither of whom took part in the first and second authors’ previous research on DLI teachers. The study was designed so that all four researchers independently analyzed and shared their analysis with the rest of the team to develop a mutual understanding of the standards and curricular resources available to Chinese DLI teachers. Student teaching occurred after the primary analysis of this study, which offered all research team members direct experience with the standards and issues discussed in the study. These new experiences allowed the research team to collectively engage in kitchen sink reflexivity and a deeper interrogation and revision of the study’s dataset and findings.

Data Sources

Two publicly available sources of data were analyzed using a *Didaktik* approach. First, the research team reviewed the Utah Core Teaching Standards on the Utah Education Network (UEN) website (<https://www.uen.org/core/>). In line with the study’s research question and the research team’s interests, the research team reviewed Utah’s social studies standards for grades 1 through 6. After reviewing the standards, lesson resources from the Utah Chinese DLI website (<https://www.utahchinesedli.org/>) were located and downloaded. The Utah Chinese DLI website contains numerous resources for administrators, teachers, and parents. Teacher resources were examined by the research team, specifically any resources related to social studies that met the criteria described below. Analyzed resources included lesson plans, handouts, a textbook, and curriculum maps, among other instructional resources. Because the state’s DLI resources were based on

the standards on the UEN web site at the time of this study—and not the revised standards that will take effect during the 2024/2025 academic year—the standards published on the UEN website were used for this analysis. Differences between the posted and revised standards are discussed below in the findings.

Data Analysis

Data analysis for this study was collaborative, occurring across three distinct stages. In the first stage, the research team examined the standards for the identified grade levels. The first author compiled all standards and objectives verbatim in a spreadsheet, then initiated structural coding by coding any standards or objectives that referenced culture (Saldaña, 2016). A broad notion of culture was used for this coding, including any standard or objective that referenced groups of people and how they lived, including beliefs, customs, holidays, traditions, languages, religions, and/or histories. After the first author coded standards and objectives, the spreadsheet was reproduced—without codes—for the other authors, who coded for culture across two assigned grade levels. Coding differences and questions were resolved after all authors completed coding, ultimately resulting in 117 agreed-upon instances of standards and objectives that referenced culture.

In the second stage of analysis, the research team's focus shifted to curriculum resources available on the Utah Chinese DLI website. The research team searched the site for any curriculum resources related to the agreed-upon standards and objectives coded in the first stage of analysis. This search yielded 15 documents across grades 1-3. For grades 4-5, no curriculum resources related to the social studies standards were located; this absence of curriculum resources was expected, because Chinese-language teachers are not responsible for teaching social studies in these grades. For Grade 6 DLI students, social studies is taught in the partner language. A total of 384 curriculum resources were downloaded from the site, which were organized in six distinct units; analysis focused on Unit 2 (Early Civilizations) and Unit 3 (Medieval and Renaissance), because these units utilized standards the research team linked to culture. To analyze these data sources, two researchers reviewed the files for their assigned grade levels, then independently drafted short analytic memos (Birks et al., 2008) based on specific curriculum resources and general impressions across the assigned data. These memos were then compared and used to theme the data (Saldaña, 2016).

After discovering Utah's revised social studies standards, which are set to take effect in the 2024/2025 academic year, a third stage of analysis was conducted. The research team decided against redoing the analysis

using the posted and soon-to-be-outdated social studies standards, because the DLI resources available to teachers were produced using the standards analyzed in the first stage of analysis. Instead, the research team repeated the procedures of the first stage of analysis to analyze the revised standards. The revised standards were arrayed in a separate set of spreadsheets, which were used to code for culture using the same broad definition of culture identified above. The first author coded all revised standards for culture independently of the rest of the research team; each of the other authors was assigned two grade levels to code for culture. Coding differences and questions were again resolved after all authors completed coding, resulting in 47 instances of standards that referenced culture. One difference between the first and third stages of analysis was the use of comparison: after coding the revised standards, all researchers compared their coding in the first and third stages and individually drafted an analytic memo summarizing similarities and differences.

Findings

The sections below focus on the resources for the DLI grade levels that are responsible for social studies instruction between grades 1 and 6. Partner-language DLI teachers in Utah are responsible for teaching social studies in grades 1-3, as well as Grade 6, whereas social studies falls under the instructional responsibilities of the English-language teacher in grades 4-5. For the grades in which partner-language teachers teach social studies, a summary of the analyzed standards and resources is presented, along with analytical commentary.

Grade 1: “I Don’t Think There Is Any Culture Integrated”

Utah’s Grade 1 social studies standards emphasized smaller-scale, local social units such as neighborhoods and communities (Table 2). Four lesson plans in the Grade 1 section of the Utah Chinese DLI website were located, all of which clearly shared the local emphasis: two lessons focused on people in the neighborhood, one examined the school in the community, and a fourth asked students to investigate how community members met their needs through making choices with money.

A scripted lesson based on Standard 1 (see Appendix A) illustrates both the local emphasis and the loose connection to teaching culture. In the lesson plan, teachers were instructed to ask questions like, “What is a family?” and to prompt students to draw and describe their own families. Although the lesson presented opportunities to discuss different family configurations, these differences were not explicitly linked to different cultural norms.

Table 2. Select grade 1 culture-related social studies standards	
Standard	Standard Text
1	Students will recognize and describe how schools and neighborhoods are both similar and different.
2	Students will recognize their roles and responsibilities in the school and in the neighborhood.
3	Students will use geographic tools to demonstrate how symbols and models are used to represent features of the school, the neighborhood, and the real world.
4	Students will describe the economic choices people make to meet their basic economic needs.

Writing about this lesson and the other Grade 1 lessons, one researcher found “[t]here is not really much related to culture” in the lesson plans. Instead, the teacher executing this lesson plan was overseeing “basic knowledge that students who are at grade level need to know in general around the world.” The goal of the lesson was the transmission of such basic—and seemingly universal—knowledge about families and communities.

Grade 2: “[E]lements in the Home Culture Are Influenced by Other Cultures”

Utah’s Grade 2 social studies standards continue the tripartite focus on people in communities, geographic tools and concepts, and basic economic principles, while also engaging civic responsibility (Table 3). As might be expected when viewing standards across grade levels, the potential scope of Grade 2 social studies expands beyond the Grade 1

Table 3. Select grade 2 culture-related social studies standards	
Standard	Standard Text
1	Students will recognize and describe how people within their community, state, and nation are both similar and different.
2	Students will recognize and practice civic responsibility in the community, state, and nation; (Objective 3a) Explain the significance of various community, state, and national celebrations (e.g., Memorial Day, Independence Day, and Thanksgiving).
3	Students will use geographic tools and skills to locate and describe places on earth; (Objective 1b) Describe how geographic aspects of the area affect a community and influence culture (e.g., river, mountain, and desert).

standards. Students are expected to learn not just about communities, but also about how people live in nations and states. Similarly, the idea of civic responsibility in Grade 2 extends beyond the school to include the community, state, and nation. In one objective of Standard 3, culture is invoked by name.

The *Interconnections: A Thematic Approach* (2010) textbook, which was created by Utah's Granite School District, illustrates how the state may expect culture to be framed in Grade 2 social studies lessons. As the title suggests, a thematic approach is used to organize the text's lessons and teaching, based on the following themes: 1) Kindness; 2) Let's Explore; 3) Around the Town; 4) Courage; and 5) America's People. Part of the lesson entitled "Community Culture Trunk" from Unit 1 helps to show the Grade 2 approach to culture:

1. Unpack your "culture suitcase." Pull out items such as a pair of chopsticks, a tortilla, a pair of moccasins, an African drum, a woven poncho, a beret, a soccer ball, a menu from an ethnic restaurant, something written in another language, a CD of Irish music, candy treat from another country, a multicultural folktale, etc. Each time you pull an item out of the suitcase ask the students where they think it came from. Once everything is out of the case, reveal that all of the items were collected from right there in their own community. Ask students to predict how so many different kinds of items can be found in their community. (p. 15)

Other lessons address differences between cultures in terms of customs and traditions found in the community and state, as well as the relationship between location and culture.

In the dyad analysis, both researchers noted an increased emphasis on culture in the Grade 2 resources but found the goal of curricular resources centered more on diversity and difference than on the teaching of Chinese culture. One researcher observed that the lessons might include histories of different countries, along with foods, animals, and symbols of other cultures or places. The other researcher analyzing Grade 2 resources found that the goal of the lessons was not to teach Chinese culture in particular—or, even, at all—but instead to help students understand that everyday practices and products in Utah homes and communities were created by and/or imported from other countries and cultures. Although not referenced in the *Interconnections* text, the lessons seemed to lay the foundation for students' understanding of globalization and its impact on contemporary life.

Grade 3: An Emphasis on Cultural Factors, But No Available Resources

The Grade 3 standards included one standard—Standard 2—that explicitly identified cultural factors as the object of study: “Students will understand cultural factors that shape a community.” Standard 2 was the only example of the coded standards where every objective listed under the standard was identified as related to culture (see Table 4 for objectives). The elements in Objective 1 continued the local focus on

Table 4. Grade 3, Standard 2 Objectives	
Standard	Standard Text
2	Students will understand cultural factors that shape a community.
Objective 1	<p>Evaluate key factors that determine how a community develops.</p> <p>Identify the elements of culture (e.g., language, religion, customs, artistic expression system of exchange).</p> <p>Describe how stories, folktales, music, and artistic creations serve as expressions of culture.</p> <p>Compare elements of the local community with communities from different parts of the world (e.g., industry, economic specialization).</p> <p>Identify and explain the interrelationship of the environment (e.g., location, natural resources, climate) and community development (e.g. food, shelter, clothing, industries, markets, recreation, artistic creations).</p> <p>Examine changes in communities that can or have occurred when two or more cultures interact.</p> <p>Explain changes within communities caused by human inventions (e.g., steel plow, internal combustion engine, television, computer).</p>
Objective 2	<p>Explain how selected indigenous cultures of the Americas have changed over time.</p> <p>Describe and compare early indigenous people of the Americans (e.g. Eastern Woodlands, Plains, Great Basin, Southwestern, Arctic, Incan, Aztec, Mayan).</p> <p>Analyze how these cultures changed with the arrival of people from Europe, and how the cultures of the Europeans changed.</p> <p>Identify how indigenous people maintain cultural traditions today.</p>

communities, asking students to examine cultural factors and their influence on the community; in one item, 1c, students were asked to compare the elements of local communities, without specifying which communities must be the subject of the comparison. The elements in Objective 2 focus on specific North American culture groups and histories, including indigenous people and their interactions with Europeans. Despite the heavy emphasis on different aspects of culture in Standard 2, the Utah Chinese DLI website does not include any available resources for teachers. Social studies lessons are listed on the site, such as *Where People Live* Parts 1 and 2, but none of the links on the site are accessible.

Grade 6: “Ancient China, Including Geography, History, and Cultural Stories”

Grade 6 represents a departure, both in terms of responsibilities for the partner-language teacher as well as the resources available on the Utah Chinese DLI website. Structurally, the DLI program shifts after Grade 5; instead of English-language and partner-language teachers sharing two groups of students throughout the day, Grade 6 partner-language teachers are independently responsible for partner-language literacy and social studies instruction. Social studies is not reinforced by an English-language teacher in Grade 6.

Partner-language teachers utilize the same teaching standards as non-DLI program social studies teachers, a sample of which can be seen in Table 5. Unlike the elementary social studies standards, which consist of a small number of standards that feature very little in the way of specific content, the Grade 6 standards identify specific social studies content students are expected to learn. Specific content includes time periods such as the Middle Ages and the Renaissance, faiths such as Islam, Christianity, and Judaism, and human rights that should be safeguarded for all people across the world. Increased responsibilities for social studies teachers—both DLI and non-DLI teachers—likely played a major role in the provision of a comprehensive series of social studies

Standard	Standard Text
1	Students will understand how ancient civilizations developed and how they contributed to the current state of the world.
2	Students will understand the transformation of cultures during the Middle Ages and the Renaissance and the impact of this transformation on modern times.

teaching resources available on the Utah Chinese DLI website, which include six units replete with lesson plans, readings, pictures, videos, and an array of activities for teachers to use. Unit 2 in the resources, which examines early civilizations, features a section entitled 古代中国 (gǔdài zhōngguó, or “Ancient China” in English). Resources in the Ancient China section include maps of China, PowerPoint slides (including slides from teachers in New York state), assignment handouts, and assessments (see Table 6), among others. Topics addressed in the resources include the Great Wall, Chinese emperors and dynasties, and background on holidays and customs such as the Dragon Boat Festival. Consistent with the demands of Standard 2, the Ancient China lesson resources focus on Chinese history and cultural traditions without connections to more recent eras or traditions evident.

Table 6. Excerpt from Grade 6 Ancient China Assessment	
Chinese Version	Translated Version
<p>古代中国考试 姓名:</p> <p>1. 哪一个是对的? A. 中国在南亚 B. 中国在西亚 C. 中国在东亚 D. 中国在东南亚</p> <p>2. 长江和黄河是从____向____流。 A. 北、南 B. 西、东 C. 东、西 D. 南、西</p> <p>3. 请看地图, 哪一个是对的? A. 中国在日本的西边 B. 俄罗斯在中国的北边 C. 太平洋在中国的东边 D. 中国在印度的南边</p>	<p>Ancient China Exam Name:</p> <p>1. Which one is correct? A. China in South Asia B. China in West Asia C. China in East Asia D. China in Southeast Asia</p> <p>2. The Yangtze River and the Yellow River flow from to. A. North, South B. West, East C. east and west D. South and West</p> <p>3. Look at the map, which one is wrong? A. China is to the west of Japan B. Russia is in the north of China C. The Pacific Ocean is to the east of China D. China is south of India</p>

Both researchers who reviewed the Grade 6 resources noted the focus on teaching Ancient China, including instruction related to China's geography, history, and cultural traditions and stories. One researcher saw links between the Ancient China lessons and other standards' focus on world religions, noting how studies of Buddhism and Confucianism "can provide Chinese language learners with valuable cultural and historical perspectives." Although the focus on Ancient China was obvious, as was its value for a Chinese DLI student, it was unclear to at least one of the researchers whether learning about Ancient China was a topic limited to Chinese DLI students or if it might be a topic examined across DLI programs and in non-DLI social studies classes as well. The Utah Education Network website includes a limited number of resources for social studies instruction related to Ancient China. However, the Spanish and Portuguese Utah DLI websites do not appear to include any lesson resources that might parallel the Ancient China resources on the Utah Chinese DLI web site.

Comparing Culture Between Utah's Revised and Current/Posted Standards

After analyzing the revised social studies standards that will take effect in the 2024/2025 school year, the research team reported fewer standards calling for cultural learning; however, the change in agreement of coded standards was strongly impacted by structural changes in the revised standards. Whereas the version of the standards analyzed in the first stage of analysis listed standards broken down into component objectives, the revised standards consist of a more concise list of standards lacking any component objectives (Table 7). Consequently, the revised standards offered fewer items to code in analysis. In Grades 3 and 6, the research team found a stronger emphasis on cultural learning in the revised standards, just as the team found in the first stage of analysis with the current standards; one researcher described the Grade 6 standards as "more relevant to culture by exploring cultural expressions, interactions, beliefs and influences on societies throughout history and the modern world." The greatest change in agreement—28 standards/objectives vs. 8 standards in the revised version—was observed in Grade 4; Grade 4's revised standards included cultural learning related to Utah cultural traditions as well as Native American groups found in Utah, but shifted focus in other standards towards pre-expansion, expansion, and post-statehood era history. The revised standards, rather than including a greater emphasis on cultural learning, appear to promote the development of young citizens who are well-

versed in American and Utah history as well as civic responsibility, which team members noted in their memos for Grades 2, 3, 4, and 5.

Table 7. Examples of consolidation between current standards and revised standards	
Select Grade 4 Social Studies Standards/Objectives	Comparable Grade 4 Revised Standards
<p>Standard 1: Students will understand the relationship between the physical geography in Utah and human life.</p> <p>Objective 2: Analyze how physical geography affects human life in Utah. Identify population concentrations in the state and infer causal relationships between population and physical geography.</p> <p>Classify the distribution and use of natural resources.</p> <p>Compare the development of industry and business in Utah as it relates to its physical geography (e.g., mining, oil, agriculture, tourism).</p> <p>Make inferences about the relationships between the physical geography of Utah and the state's communication and transportation systems (e.g., trails, roads, telegraph, rail lines).</p> <p>Examine the interactions between physical geography and public health and safety (e.g., inversions, earthquakes, flooding, fire).</p> <p>Explain how archaeology informs about the past (e.g., artifacts, ruins, excavations).</p>	<p>Standard 4.1.2: Examine maps of Utah's precipitation, temperature, vegetation, population, and natural resources; make inferences about relationships between the data sets. Describe how and why humans have changed the physical environment of Utah to meet their needs (for example, reservoirs, irrigation, climate, transcontinental railroad).</p> <p>Standard 4.1.3: Describe how the physical geography of Utah has both negative and positive consequences on our health and safety (for example, inversions, earthquakes, aridity, fire, recreation).</p>

Discussion and Conclusion

The purpose of this case study was to examine Utah's social studies standards, the instructional resources provided by the state for Chinese DLI teachers, and, most importantly, the ways these resources support cultural learning for DLI students. Through a collaborative, *Didaktik* analysis of the standards and resources, the study helps to illustrate how the provided instructional resources enabled Chinese DLI teachers to

simply teach Americentric or acultural social studies content in the Chinese language. Across the Grades 1 and 2 resources, Chinese cultural knowledge or learning was not explicitly emphasized. In Grade 3, only one objective and no resources addressed cultural knowledge. Grade 6 represented the one exception during the years in which DLI teachers are responsible for teaching social studies in the partner language. Among the Grade 6 social studies resources available for Chinese DLI teachers was a unit on ancient civilizations, which included extensive materials for lessons on Ancient Chinese civilization and culture. Despite this well-developed set of resources, it was unclear whether Ancient China constituted a topic unique to the Chinese DLI program social studies classes or if this was a topic that might be learned by many students—both DLI and non-DLI—across the state because of standards focusing on ancient civilizations.

Social studies can play a potentially transformative role in DLI students' learning, yet the subject's potential may be hindered by the structure of Utah's DLI program. DLI programs, both within and beyond Utah, are promoted in large part because of the benefits associated with these programs, including the cultivation of cultural competence or awareness (e.g., Soderman, 2015; Sung & Tsai, 2019). Second language learning and the accrual of cultural competence or awareness each might constitute powerful knowledge, given their potential to contribute to "the development of human powers" (Deng, 2021, p. 1654). Yet the close relationship, if not interdependence, between the two identified by scholars (e.g., Brameld, 1957; Hollins, 1996; Jiang, 2000; Kim, 2019) suggests a reciprocal relationship: the ability to communicate in a second language allows the learner to participate in a culture in a dramatically different way, just as learning about the culture of a group can enhance one's understanding of both people and language. In DLI settings, cultural learning is essential to students' learning and transformation, yet programmatic requirements limit social studies instruction to less than 10% of instructional minutes. Reflecting the plight of elementary social studies nationwide (Demoiny, 2020; Heafner & Fitchett, 2012), the limited time Utah DLI teachers allocate to, and the resources they are provided for, social studies may ultimately decrease or inhibit the teaching of culture, and thus DLI programs' transformative potential.

Decreased or inhibited teaching opportunities for cultural knowledge raise two points that should be made. First, this paper has demonstrated that even though Utah's elementary social studies standards include multiple entry points for the teaching of culture—including the culture of the partner language in DLI programs—not all teaching standards afford such opportunities. The Grade 3 standards referenced in Table 4 present examples of Americentric social studies

content learning in which even a comparative approach to minority populations in China might be challenging, and even unproductive, given the demands of the standards. Second, culture is certainly not the exclusive domain of the social studies; teaching culture can, and likely is, done during DLI partner language literacy instruction and across many second language classrooms outside of DLI programs as well, despite the difficult questions and debates it presents (Byrd, 2014; Jacobson, 1996). However, as An's quote at the beginning of the paper helps to illustrate, the teaching of cultural knowledge may not happen as often as DLI teachers think it should happen, given the responsibilities and programmatic limitations DLI teachers face.

The decision of when and how to teach culture may lie primarily with individual DLI teachers, who must negotiate their own ideologies with the needs of their learners along with programmatic requirements (Davis & Yan, 2023; Henderson & Palmer, 2020; Sung & Tsai, 2019; Yan & Davis, 2023). Chinese teachers are recruited to teach in DLI programs from across the US and from China, and many teachers who teach in Utah DLI schools may not be experienced teachers (Davis & Yan, 2023; Peng, 2016; see also Yan & Davis, 2023). Teachers who have taught in Utah's DLI program have consistently noted challenges that heavily impact content area teaching, specifically the instructional requirements of the DLI program and the lack of Chinese-language resources that are both available and written in an accessible language for Chinese DLI students (e.g., Davis & Yan, 2023; Sung & Tsai, 2019; Yan & Davis, 2023). In addition to limited resources, Chinese DLI teachers must also contend with the fact that DLI students spend much less time learning social studies in elementary school, which may impact their partner-language domain-specific vocabulary development and their success in other content area classes (Davis & Yan, 2023). Chinese DLI teachers may have a desire to teach culture more explicitly and comprehensively than they do, yet they may be unsure about the permissibility of such efforts given DLI program requirements, and/or they may lack—or be unable or unwilling to develop—instructional resources to carry out such teaching.

With the revised social studies standards set to be binding in 2024, the issue of cultural learning in DLI classrooms may be further complicated. The resources available on the Chinese DLI web site are all based on the current, outgoing standards; although the research team found similarities between the current and revised standards, an expansion of historical learning and civic responsibility was noted by the team in the third stage of analysis. Resources available on the Chinese DLI web site may not be entirely invalidated by these changes, but some lesson plans and resources may not align to the revised standards.

Changes to the standards may place increased pressure on teachers, particularly teachers developing activities that engage both cultural learning in the partner language's culture along with the cultural learning explicitly required by the revised standards. Revision of the Chinese DLI social studies resources to be reflective of the revised standards seems an essential next step, along with consideration of how to provide resources and lesson ideas to engage cultural learning in the partner-language culture.

Despite the limitations this study may present, the study's authors see a need for greater attention and increased scholarship in social studies education within DLI programs like the one in Utah. This paper presents the results of a preliminary *Didaktik* curriculum analysis. Teaching standards and publicly available curriculum resources developed by the Utah Chinese DLI program were analyzed; because of time constraints, the research team did not observe social studies lessons in DLI classrooms, nor were DLI teachers surveyed or interviewed for this study. Nevertheless, there is tremendous importance and transformative potential in teaching culture within social studies lessons and not just in second language learning lessons. Lacking instruction in the partner-language culture, social studies lessons in the DLI program may represent something of a missed opportunity. As two of this study's authors have found in related work (e.g., Davis & Yan, 2023; Yan & Davis, 2023), DLI teachers would benefit from tailored professional development, in content area instruction as well as in curriculum integration, an approach used in elementary schools to make greater use of social studies in conjunction with other teaching areas (see Demoiny, 2019). Research in DLI program content area instruction, and even content area instruction across bilingual education programs, remains limited. The simultaneous challenges of DLI program growth across the country (Henderson & Palmer, 2020) and the reduction in social studies instruction (Demoiny, 2020) present opportunities, needs, and challenges for both research and teacher professional development.

References

American Council on the Teaching of Foreign Languages. (2023). World-readiness standards for learning languages: The roadmap to language competence. Retrieved June 1, 2023, from <https://www.actfl.org/educator-resources/world-readiness-standards-for-learning-languages>.

An, S. (2017). Preparing elementary school teachers for social studies instruction in the context of edTPA. *The Journal of Social Studies Research, 41*, 25-35. <http://dx.doi.org/10.1016/j.jssr.2015.10.002>.

Au, W. (2009). Social studies, social justice: W(h)ither the social studies in high-stakes testing? *Teacher Education Quarterly, 36*(1), 43-58. <https://www.jstor.org/stable/23479200>.

Banks, J.A. (1995). Multicultural education and curriculum transformation. *The Journal of Negro Education, 64*(4), 390-400. <https://www.jstor.org/stable/2967262>.

Birks, M., Chapman, Y., & Francis, K. (2008). Memoing in qualitative research: Probing data and processes. *Journal of Research in Nursing, 13*, 68-75. <https://doi.org/10.1177/1744987107081254>.

Brameld, T. (1957). *Cultural Foundations of Education*. New York: Harper & Brothers.

Brophy, J., & Alleman, J. (2006). A reconceptualized rationale for elementary social studies. *Theory & Research in Social Education, 34*(4), 428-454. <http://dx.doi.org/10.1080/00933104.2006.10473317>.

Brophy, J., & Alleman, J. (2002). Learning and teaching about cultural universals in primary-grade social studies. *The Elementary School Journal, 103*(2), 99-114. <https://www.jstor.org/stable/1002230>.

Byrd, D. (2014). Learning to teach culture in the L2 methods course. *Electronic Journal of Foreign Language Teaching, 11*(1), 76-89.

Byrd, D.R., Hlas, A.C., Watzke, J., & Montes Valencia, M.F. (2011). An examination of culture knowledge: A study of L2 teachers' and teacher educators' beliefs and practices. *Foreign Language Annals, 44*(1), 4-39.

Colantonio-Yurko, K., Heidt, M.A., & Szilagyi, J. (2023). Third culture and cross-cultural kids: Supporting bi/multilingual students with many cultural identities and experiences. *The Clearing House 96*(2), 52-60. <https://doi.org/10.1080/00098655.2023.2165473>.

Davis, W.J., & Yan, J. (In press). “[I]t’s harder for us as Chinese teacher[s]”: Science content instruction in Chinese DLI programs. In K. Sung (Ed.), *Chinese-English Dual Language Immersion Programs: Content Area Instruction, Learners, and Evaluation*. Lexington Books

Demoiny, S.B. (2020). Preparing elementary pre-service teachers for social studies integration in an alternative field placement. *The Journal of Social Studies Research*, 44(1), 51-59. <https://doi.org/10.1016/j.jssr.2019.08.003>.

Deng, Z. (2021). Powerful knowledge, transformations and *Didaktik*/curriculum thinking. *British Educational Research Journal*, 47(6), 1652-1674. <https://doi.org/10.1002/berj.3748>.

Folkes, L. (2022). Moving beyond 'shopping list' positionality: Using kitchen table reflexivity and in/visible tools to develop reflexive qualitative research. *Qualitative Research*, 23(5), 1301-1318. <https://doi.org/10.1177/14687941221098922>.

Fui, C.M. (2019). Teaching the enduring understandings about culture in primary social studies. *HSSE Online*, 8(2), 13-18.

Hamilton, D., & Gudmundsdottir, S. (1994). *Didaktik* and/or curriculum? *Curriculum Studies*, 2(3), 345-350. <https://doi.org/10.1080/0965975940020305>.

Heafner, T.L., & Fitchett, P.G. (2012). Tipping the scales: National trends of declining social studies instructional time in elementary schools. *The Journal of Social Studies Research*, 36(2), 190-215.

Henderson, K.I., & Palmer, D.K. (2020). *Dual Language Bilingual Education: Teacher Cases and Perspectives on Large-scale Implementation*. Bristol, UK: Multilingual Matters.

Hirsch, Jr., E.D. (1988). *Cultural Literacy: What Every American Needs to Know*. New York: Vintage Books.

Hollins, E.R. (1996). *Culture in School Learning: Revealing the Deep Meaning*. Mahweh, NJ: Lawrence Erlbaum Associates.

Interconnections: A thematic approach. Salt Lake City, UT: Granite School District. <https://drive.google.com/file/d/13Qs3GXfRPvS-xkP9GzUr89cbzpYLjhlml/view>

Ivenz, P., & Reid, E. (2022). Development of students' intercultural communicative competence via creating their own cultures. *Journal of Language and Cultural Education*, 10(1), 61-69. <https://doi.org/10.2478/jolace-2022-0006>.

Jacobson, W. (1996). Learning, culture, and learning culture. *Adult Education Quarterly*, 47(1), 15-28.

Jiang, W. (2000). The relationship between culture and language. *ELT Journal*, 54(4), 328-334.

Kim, D. (2020). Learning language, learning culture: Teaching language to the whole student. *ECNU Review of Education*, 3(3), 519-541. <https://doi.org/10.1177/2096531120936693>.

Kramersch, C. (1993). *Context and Culture in Language Teaching*. Oxford: Oxford University Press.

Kramersch, C. (2009). Third culture and language education. In L. Wei and V. Cook (Eds.), *Contemporary Applied Linguistics*, Volume 1 (pp. 233-254). New York: Bloomsbury Academic.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, 32(3), 465-491. <https://www.jstor.org/stable/1163320>

Li, J., Steele, J., Slater, R., Bacon, M., & Miller, T. (2016). Teaching practices and language use in two-way dual language immersion programs in a large public school district. *International Multilingual Research Journal*, 10(1), 31-43. <http://dx.doi.org/10.1080/19313152.2016.1118669>.

Moore, A.M., & Barker, G.G. (2012). Confused or multicultural: Third culture individuals' cultural identity. *International Journal of Intercultural Relations*, 36, 553-562. <https://doi.org/10.1016/j.ijintrel.2011.11.002>.

National Council for the Social Studies. (n.d.). National curriculum standards for social studies; Chapter 2—The themes of social studies. Retrieved May 26, 2023, from <https://www.socialstudies.org/national-curriculum-standards-social-studies-chapter-2-themes-social-studies>.

O'Connor, K.A., Heafner, T., & Groce, E. (2007). Advocating for social studies: Documenting the decline and doing something about it. *Social Education*, 71(5), 255-260.

Pascopella, A. (2013). Utah's languages of opportunity. *District Administration*, 49(11), 57-61.

Passe, J. (2006). New challenges in elementary social studies. *The Social Studies*, 97(5), 189-192. <http://dx.doi.org/10.3200/TSSS.97.5.189-192>

Peng, K. (2016). Chinese as a foreign language in K-12 education. In J. Ruan, Jie Zhang, & Cynthia B. Leung (Eds.), *Chinese Language in the United States* (pp. 123-140). Cham, Switzerland: Springer International Publishing Switzerland. https://doi.org/10.1007/978-3-319-21308-8_7

Peterson, E., & Coltrane, B. (2003). Culture in second language teaching. *ERIC Clearinghouse on Languages and Linguistics*. EDO-FL-03-09. Washington, DC: Center for Applied Linguistics. Retrieved June 1, 2023 from https://www.researchgate.net/publication/237500367_Culture_in_Second_Language_Teaching.

Saldaña, J. (2016). *The Coding Manual for Qualitative Researchers* (3rd ed.). Los Angeles: SAGE Publications.

Schlein, C., Taft, R.J., & Ramsay, C.M. (2016). The intersection of culture and behavior: Intercultural competence, transnational adoptees, and social studies classrooms. *Journal of International Social Studies*, 6(1), 128-142.

Snow, C.P. (1964). *The Two Cultures and the Scientific Revolution* (2nd ed.). Cambridge, UK: Cambridge University Press. (Original work published 1959)

Soderman, A.K. (2010). Language immersion programs for young children? Yes...but proceed with caution. *Phi Delta Kappan*, 91(8), 54-61.

Spicer-Escalante, M. L. (2017). Introduction to dual language immersion. In K. deJonge-Kannan, M.L. Spicer-Escalante, E. Abell, & A. Salgado (Eds.), *Perspectives on Effective Teaching in DLI and Foreign Language Classrooms* (pp. 3-15). Logan, UT: Department of Languages, Philosophy, and Communication Studies, Utah State University.

Steele, J.L., Watzinger-Tharp, J., Slater, R., Roberts, G., & Bowman, K. (2019). *Research Brief: Student Performance under Dual Language Immersion Scale-up in Utah*. Utah State Board of Education. Retrieved May 18, 2023, from https://www.americancouncils.org/sites/default/files/documents/pages/2019-11/Research%20Brief-%20IES%20UTAH%20STUDY%20FINDINGS_0.pdf.

Sung, K.Y., & Tsai, H.M. (2019). *Mandarin Chinese Dual Language Immersion Programs*. Bristol, UK: Multilingual Matters.

Ukpokodu, O. (2011). Developing teachers' cultural competence: One teacher educator's practice of unpacking student culturelessness. *Action in Teacher Education*, 33(5-6), 432-454. <https://doi.org/10.1080/01626620.2011.627033>

Utah Dual Language Immersion. (2017). Dual language immersion instructional time. Retrieved May 18, 2023, from <https://www.utahdli.org/instructionalmodel.html>.

Utah Education Network. (n.d.). Social studies – 3rd grade. Retrieved May 26, 2023, from <https://www.uen.org/core/core.do?courseNum=6030>.

Werler, T.C., & Tahirsylaj, A. (2022). Differences in teacher education programmes and their outcomes across *Didaktik* and curriculum traditions. *European Journal of Teacher Education*, 45(2), 154-172. <https://doi.org/10.1080/02619768.2020.1827388>.

Yan, J., & Davis, W.J. (2023). A case study of Chinese teachers' professional learning in a Chinese dual language immersion program. *Educational Research: Theory and Practice*, 34(2), 48-56.

Young, M., & Muller, J. (2013). On the powers of powerful knowledge. *Review of Education*, 1(3), 229-250. <https://doi.org/10.1002/rev3.3017>.

Appendix A

Grade 1 Lesson Plan: Families in Our Neighborhood		
Grade 1	Lesson: Families in Our Neighborhood	Reference to English Interconnections Lesson Families in Our Neighborhood pg.75
Social Studies Standard(s): Standard 1 Objective 1		
Content Objective(s): Students will identify their family members. <i>I can identify my family members.</i>		Language Objective(s): Students can say mom, dad, brother and sister. <i>I can say mom, dad, brother and sister.</i>
Essential Questions: How are things both similar and different in my neighborhood?		Required Academic Vocabulary for Word Wall: Listen: mom, dad, sister, brother, family Speak: mom, dad, sister, brother Read: Write: Sentence Frames:
Materials: • Blank paper for students (1 each) • Crayons, markers		Additional Lesson Vocabulary: Change, needs, graph
Lesson:		Instructional Time: 20 minutes
<p>Opening: (2 minutes)</p> <ul style="list-style-type: none"> Draw a house on the board. <p>T: "Today we are talking about families." T: "What is a family?" S: will respond. (answers will vary) • Validate the student responses.</p> <p>Introduction to New Material (Direct Instruction): (3 minutes)</p> <p>T: "This is my family." • Show the students a picture of your family.</p> <p>T: "I have a mom." • Point out your mom in the picture. • Draw your mom on the board in the house and label it.</p> <p>T: "I have a dad." • Point out your dad in the picture. • Draw a picture of your mom on the board in the house.</p> <p>T: "I have a _____." • Go through the members of your family that are in the picture and draw them on the board inside the house.</p> <p>T: "This is my family. I have a mom, a dad, _____."</p> <p>Independent Practice: (6 minutes)</p> <p>T: "Now it is your turn to draw your own family." T: "I am going to give each of you a piece of paper. When you get your paper, you need to go to your desk and draw your family. You will draw your mom, dad, sister, brother... You have 5 minutes." • Teacher will pass out white papers. • Teacher will walk around the room asking the students about the people in their families. S: will go to their desks and draw their families. T: "You have 1 more minute." T: "10,9,8,7,6,5,4,3,2,1. Time is up. You need to clean up, come sit on the carpet and bring your picture with you."</p> <p>Guided Practice (5 minutes) <i>Modeling Cycle</i> <u>Teacher Does:</u> T: "Now I want you to tell your neighbor about your family. But first let's practice." <u>Teacher Does with 1 Student:</u> T: "I need a student to come up and help me." • Teacher will choose a student and they will come up with their picture of their family. T: "This is my family. My mom, my dad..." (point at people as you say them) T: "Look at your picture and tell me about your family."</p>		

S: *will respond, "mom, dad, sister..."*

- Help students as needed by prompting.
- Repeat the students after they say the family members

T: "Great job!"

2 Students Do:

T: "Now I need 2 students to come up and help me."

- Teacher chooses 2 students with their drawings.

T: "I want you to tell your partner about your family."

S: *will tell each other about their families one at a time.*

T: "Awesome! Please sit down."

All Students Do:

T: "Now it is your turn to turn to your neighbor and tell them about your family."

S: *will turn to their neighbor and tell them about their family using the drawing.*

Introduction to New Material: (4 minutes)

T: "We just learned about each others families!"

T: "Are all the families the same?"

S: *will respond, "no."*

T: "No, not all families are the same. My family has ___ people. Amy's family has 3 people. They are different."

T: "Will all families stay the same?"

S: *will respond, "no."*

T: "Families can change when new babies are born..."

T: "So, families are always changing."

Closing: (1 minutes)

T: "Next time we are going to graph our families! So, please hand me your drawings and we will use them next time."

Assessment:

Drawing of the family

Extra Ideas:

Implementing the Teaching Self Efficacy Development Initiative

Todd J. Wentz

Abstract

More and more, colleges and universities and even K-12 settings across the United States and throughout the world are relying on adjunct instructors to teach classes in their field of expertise. Previous literature has shown that adjunct instructors often have little formal preparation for teaching, and even when some preparation is offered, it is often insufficient to establish teaching self-efficacy in the classroom. This study examined changes in teaching self-efficacy after adjunct instructors were provided information (articles) around constructivist teaching strategies within collaborative Community of Practice (CoP) meetings to discuss those strategies. The study was conducted at a small private college that relies heavily on adjunct instructors to conduct classes. A quantitative pre/post survey and qualitative comments throughout the intervention sessions were used to examine changes. Participants reported a significant increase in teaching self-efficacy, which was especially prominent among new instructors compared with those with more experience. There was also a self-reported increase in the use of more constructivist strategies within their classes over the course of the intervention. Participants also indicated that the CoP meetings were critical to both learning and application of strategies in practice.

Introduction

Across the United States and internationally, more teaching is being performed by adjunct faculty, sometimes referred to as contract teachers, casual academics, or, in the case of K-12 settings, paraprofessionals or paraeducators (Shattuck et al., 2011, Thirolf, 2013; Baik et al., 2018; Flaherty, 2018; Will, 2022). Throughout this paper, all classifications will be referred to adjunct faculty. The increased reliance on adjunct faculty brings benefits. For instance, on the collegiate level an increase in adjunct instructors allows increased time for full-time faculty to conduct research and advise students in their studies (Thirolf, 2013) and provides students the opportunity to learn from working professionals who may provide more contextually rich instruction (Morton, 2012; Bautista & Cipagauta, 2019). It also brings challenges, because adjunct faculty often have no training or experience in teaching in academic settings (Baik et al., 2018; Will, 2022). Without this preparation, teaching self-efficacy (TSE) may be lacking, resulting in less effective and engaging teaching (Morton, 2012; Bautista & Cipagauta, 2019). Thus, it falls to the hiring institution to provide some sort of training to increase TSE among adjuncts to ensure that the quality of the education provided meets the needs and expectations of both students and, eventually, the employers of those students upon graduation (Morton, 2012; Thirolf, 2013; Paul, 2015; Maksymchuk et al., 2018; Bautista & Cipagauta, 2019).

TSE, Learning Frameworks, and Community of Practice

TSE is a particular construct that has grown out of Bandura's (1997) work on self-efficacy theory. Self-efficacy can be defined as an individual's belief in his or her ability to successfully take particular action within a specific framework of expectations and is developed through four key ingredients: verbal persuasion, vicarious experience, mastery tasks, and physiological and affective states (Bandura, 1997). TSE then is an instructor's belief that particular actions can be taken in a teaching environment that will lead to successful student engagement and learning and can be said to be developed through the encouragement of experienced others (verbal persuasion), watching others perform teaching tasks (vicarious experience), practicing the particular tasks (mastery tasks), and reflecting on the outcomes of the practice (physiological and affective states). When training is provided that supports these four factors, TSE is more likely to develop early, but when training does not support these four factors, TSE is likely to come slowly,

if at all (Morton, 2012; Thirolf, 2013; Paul, 2015; Maksymchuk, 2018; Bautista & Cipagauta, 2019).

Initial training is critical, but training must not stop there. In-service meetings and professional development opportunities must be provided and in a way that allows adjuncts to take advantage of them just as full-time instructors can (Thirolf, 2013; Wicks et al., 2020). Some institutions implement mentoring programs for new faculty. These programs, when well structured and thoughtfully administered, can be of enormous benefit to new adjunct faculty in their first forays into collegiate teaching. However, it is worth noting that these programs also take significant time for both the faculty mentors and the new adjunct faculty receiving the support (Shattuck et al., 2011; Morton, 2012; Baik et al., 2018). Whatever format training for adjunct instructors takes, it is clear that without the development of TSE, the ability of the instructor to be successful, in both the long term and the short, is in question (Thirolf, 2013).

Successfully helping students learn in the higher education setting is most likely to occur when instructors understand and apply sound pedagogical and andragogical principles, including an understanding of constructivism (Merriam et al., 2007). The Merriam-Webster online dictionary (2022) defines pedagogy as “the art, science, or profession of teaching.” To obtain a teaching license, K-12 teachers must complete a university degree program in teaching. Such programs are often rich in pedagogy. Conversely, paraeducators and adjunct collegiate and university instructors are not required to go through such programs. As a result, their understanding of the art and science of teaching is often understandably incomplete (Baik et al., 2018; Will, 2022).

Closely related to pedagogy is andragogy, which is defined as “the art or science of teaching adults” (Merriam-Webster, 2022). Andragogy in the United States was championed by Malcolm Knowles beginning in the 1950s. Andragogy posits that adults are able to approach learning differently than children as a result of several key factors, including a more mature self-concept, increased experience and readiness to learn, and a change in orientation toward learning activities and motivations to learning (Smith, 2002). These concepts can inform the way that higher education instructors engage with their students.

Constructivism as an educational philosophy suggests that students develop, or construct, personal meaning about concepts and ideas as they apply the concepts and ideas to specific challenges (Derry, 2013). A central theme of constructivism is that presentation of material by an experienced instructor is useful, but meaning is created through active use of the information in authentic settings (Derry, 2013). Additionally, successful instruction has often been described as student centered,

which is best typified by instructors employing constructivist strategies and empowering students to take an active role in the creation of their own learning processes including developing assessments (Klemenčič, 2020).

Among the constructivist tools frequently used are problem-based learning (PBL), cooperative learning (CL), and inquiry-based learning (IBL) (University of Buffalo, n.d.). Although related, these concepts are subtly different. In PBL, learners are presented with real-world situations and allowed to work on their own to find, create, and propose solutions. Closely related to PBL is CL, in which students are presented with real-world problems, as with PBL, but are then placed in groups to work through the process of finding and preparing solutions (University of Buffalo, n.d.). In IBL, learners are encouraged to pose their own questions and create insights and connections as they look for and find their own unique solutions while instructors fill the role of guide or designated questioner.

Implementing IBL, PBL, or CL strategies successfully requires training and practice to maximize the effectiveness of the strategy as instructor involvement is still critical and necessary (University of Buffalo, n.d.). These strategies are in harmony with the concept of student-centered learning but are not necessarily familiar to adjunct faculty because they are relatively recent developments in pedagogical strategies (Roehl et al., 2013). When attempting to bring adjunct instructors up to speed, institutions would be wise to consider implementing a Community of Practice (CoP) framework.

A CoP is a group of individuals who share a desire to deepen understanding around a concept, idea, or body of knowledge (Wenger-Trayner & Wenger-Trayner, 2015). Integrating a CoP to strengthen information being shared with new instructors has been shown to be effective. Baik and colleagues (2018) and Thirolf (2013) separately concluded that if initial didactic training programs were not followed with opportunities for reinforcement, discussion, and further development, the sense of TSE suffers and the success of the instructor begins to diminish.

Purpose of this Study

This study investigated whether a training program that included focused training around constructivist teaching strategies within the context of a CoP could result in greater TSE among the participants. The training was designed to provide experiences in all factors that support the development of TSE with the intent of helping instructors feel more confidence in their ability to use the selected strategies in real classrooms

with real students. The primary research question was framed to observe self-reported changes in TSE and the use of constructivist strategies; the second research question was concerned with identifying which aspects of the program were most useful in creating any observed changes by the participants themselves.

Research Questions

1. What impact did the Teaching Self-Efficacy Development Initiative (T-SEDI) program have on:
 - a. Teaching self-efficacy (TSE)?
 - b. Self-reported use of constructivist strategies?
2. What did participants find to be the most effective aspects of the T-SEDI program?

Methods

This study was conducted using the Action Research (AR) process (Mertler, 2020). AR differs from theoretical research in that the intention of AR is to solve problems appearing in the regular practice of the researcher.

Setting

This AR project took place in the business department of a small private college in the Mountain West. In the business department, approximately 80% of instructors were considered adjunct, voluntary, or some other non-full-time compensated designation.

The existing training program for new adjunct instructors was facilitated through a Canvas course supplemented with a website providing non-course-specific information and a two-hour face-to-face orientation. Much of the training was focused on policy, procedure, and the use of Canvas as a tool, with little time spent specifically helping new adjuncts develop TSE. Ongoing faculty development activities consisted of regular faculty meetings and annual “all-hands” meetings held prior to the start of each school year. These meetings were typically scheduled during times that were difficult for adjuncts to attend.

Participants

All new instructors in the business department hired between Fall 2021 and Fall 2022 were required to participate in the T-SEDI as part of their acceptance of teaching responsibilities for the college. Additional

participants came from the instructional staff in the business department and included two full-time faculty and three additional adjuncts. All participants had significant business experience and had earned master's degrees, but none had earned terminal degrees. One participant dropped by request before the study was completed

Role of the Researcher

The researcher was the primary developer of the T-SEDI program. Members of the college's business department reviewed and provided feedback during the creation of all materials to ensure consistency in messaging with existing orientation program materials. The researcher distributed all materials, administered all data collection measures, conducted and observed meetings, and completed all data analysis and interpretation of results.

Procedures

E-mail invitations were sent to all business faculty, with new adjunct faculty informed of the requirement of their participation as part of their first year of teaching as an adjunct. Participants were allowed to sign electronic or hard-copy disclosure forms before beginning the study.

The pre- and post-innovation survey instruments comprised an adapted form of the Teacher's Sense of Self Efficacy Scale Short Form, hereafter referred to as the Scale (Tschannen-Moran & Woolfolk Hoy, 2001). The Scale consisted of 12 questions, although for the purposes of this study, one question addressing work with families was removed, because participants' students were all adults. Additionally, the wording of many questions was adjusted to be more applicable to collegiate instruction. Examples of questions from the Scale included "How much can you do to motivate students who show low interest in schoolwork?" and "To what extent can you craft good questions for your students?"

Data from survey instruments were grouped into specific constructs of TSE, namely instructional strategies (questions 5, 9, 10, and 11), student engagement (questions 2, 4, and 7), and classroom management (questions 1, 3, 6, and 8). Participant data were also grouped by demographic indicators (new adjuncts and experienced instructors) within those constructs. Paired sample t-tests were performed for each demographic group to identify any change in expressions of TSE from the pre-innovation survey to the post-innovation survey. The post-innovation survey instrument also requested feedback from participants regarding overall impressions of the program. Surveys responses were collected via SurveyMonkey for pre- and post-innovation survey instruments.

The T-SEDI program consisted of activities designed to directly address all four aspects of self-efficacy development, namely working with master tasks, providing opportunities for verbal persuasion, having an opportunity to reflect on emotional and physiological states brought about while working with the development process, and vicarious experience. At approximately week four of the semester, participants were e-mailed an article dealing with PBL and were then invited to a CoP meeting two weeks later to discuss the article and possible implementation of its insights. After another two weeks, the second article focused on CL was e-mailed, and two weeks after that the second CoP meeting was convened. Meetings were recorded for later analysis.

Analysis

Pre- and post-innovation survey scores were compared individually and by experience groupings across the survey in its entirety. Meeting notes were coded and compared across sessions to identify changes in participants' comments related to TSE over the course of the intervention. Codes and comments from early and later sessions were compared to identify possible changes in the ways that participants discuss their instructional strategies, student engagement, and classroom management.

To answer the second research question, "What did participants find to be the most effective aspects of the T-SEDI program?" two questions were added to the post-innovation survey. One asked the participants to indicate their opinion as to the impact of the different training modalities employed (specific articles or CoP discussion meetings) and the other was an open-ended question encouraging participants to share additional perceptions of what they found to be the most helpful and influential components of the T-SEDI program. Meeting notes were coded and evaluated with regard to identifying participants' statements regarding aspects of the innovation they found to be particularly impactful.

In analyzing both questions, participants' responses were also evaluated in groupings based on years of experience and type of teaching experience participants identified themselves possessing in the pre-innovation survey instrument.

Results

Both qualitative and quantitative analyses were used to evaluate changes that occurred as a result of the T-SEDI program and which aspects of the program participants found most useful. Survey instruments provided quantitative results and meeting notes and

observations were analyzed for qualitative findings. The T-SEDI program was intended to enhance the teaching self-efficacy of adjunct teachers in a small collegiate environment.

Question 1a: Did T-SEDI Improve Teaching Self-Efficacy?

Responses were analyzed using a paired samples t-test for each question individually and on the composite average of responses. An alpha level of .05 was used to determine significance. These results are displayed in Table 1. No statistically significant change was seen in any questions on the survey instruments from pre- to post-innovation for the full sample.

A dichotomous variable for instructor experience was created with a cut-off of three years. Five instructors had more than three years'

Table 1. Paired samples t-test for all participants by question

Question	Pre-Innovation M(SD)	Post Innovation M(SD)	<i>p</i>
Controlling disruptive behavior	7.78(.97)	7.56(1.01)	.26
Motivating students showing low interest	6.22(1.72)	6.22(1.56)	.50
Calm disruptive students	7.67(1.23)	7.11(.78)	.07
Helping students value learning	7.11(1.57)	7.00(1.58)	.30
Crafting good questions	7.78(.83)	8.11(.78)	.20
Getting students to follow classroom rules	7.44(1.13)	7.44(1.81)	.50
Getting students to believe they can do well	7.33(.71)	7.22(1.39)	.36
Establish a classroom management system*	7.88(.84)	7.88(.64)	.5
Using a variety of assessment strategies	7.22(.83)	7.44(1.59)	.35
Providing alternative explanations or example	7.67(1.00)	8.11(.60)	.17
Implementing alternative teaching strategies	7.00(1.00)	7.44(1.51)	.24
Entire Survey Average	7.34(.57)	7.40(.80)	.42

*One instructor left the question unanswered.

experience teaching in a higher education setting and were considered “experienced.” The remaining four instructors had less than three years’ experience and were considered “new.” Paired samples t-tests were then conducted within each group. The results are shown in Tables 2 (experienced) and 3 (new).

As Table 2 shows, experienced instructors saw a statistically significant negative change with regard to question 3, “calming disruptive students” at the conclusion of the innovation ($M=7.20$, $SD=.84$) as compared with before the innovation ($M=8.2$, $SD=.83$; $t(4df)=2.24$, $p=.05$), suggesting that they felt less able to calm disruptive students after the intervention than at the beginning. No other statistically significant change was shown in this comparison of experienced instructors on all questions.

Table 2. Paired samples t-test for experienced instructors

Question	Pre-Innovation M(SD)	Post Innovation M(SD)	<i>p</i>
Controlling disruptive behavior	8.00(1.00)	7.40(1.14)	.15
Motivating students showing low interest	5.60(2.19)	5.80(1.92)	.41
Calm disruptive students	8.20(.83)	7.20(.84)	.05*
Helping students value learning	6.40(1.51)	6.00(1.23)	.09
Crafting good questions	8.20(.83)	7.80(.84)	.09
Getting students to follow classroom rules	7.60(1.14)	7.00(2.35)	.28
Getting students to believe they can do well	7.20(.84)	6.60(1.52)	.10
Establish a classroom management system**	8.00(.82)	8.00(.82)	.50
Using a variety of assessment strategies	7.40(1.14)	6.80(1.79)	.25
Providing alternative explanations or example	8.40(.55)	8.00(.00)	.09
Implementing alternative teaching strategies	7.40(.89)	6.80(1.64)	.21
Entire Survey Average	7.44(.70)	7.00(.72)	.12

* $p<.05$

**Question was left unanswered by one participant.

Table 3 shows that new instructors saw several more statistically significant changes in their survey responses about instructional strategies. New instructors showed significantly greater understanding of “crafting good questions” at the end of the innovation ($M=8.50$, $SD=.58$) than before the innovation began ($M=7.25$, $SD=.50$; $t(3df)=-2.6$, $p=.04$). Statistically significant changes for “using a variety of assessment strategies” were seen at the end of the program ($M=8.25$, $SD=.96$) compared with before the program ($M=7.00$, $SD=.00$; $t(3df)=-2.61$, $p=.04$). Statistically significant changes were also seen in “providing alternative explanations or example” (post-innovation $M=8.25$, $SD=.96$; pre-innovation $M=6.75$, $SD=.5$; $t(3df)=-2.32$, $p=.05$) and in “implementing alternative teaching strategies” (post-innovation $M=8.25$, $SD=.96$; pre-innovation $M=6.50$, $SD=1$, $t(3df)=-2.782$, $p=.04$).

Table 3. Paired samples t-test for new instructors

Question pair	Pre-Innovation M(SD)	Post Innovation M(SD)	<i>p</i>
Controlling disruptive behavior	7.50(1.00)	7.75(.96)	.20
Motivating students showing low interest	7.00(.00)	6.75(.96)	.32
Calm disruptive students	7.00(1.41)	7.00(.82)	.5
Helping students value learning	8.00(1.16)	8.25(.96)	.20
Crafting good questions	7.25(.50)	8.50(.58)	.04
Getting students to follow classroom rules	7.25(1.26)	8.00(.82)	.11
Getting students to believe they can do well	7.50(.58)	8.00(.82)	.09
Establish a classroom management system*	7.75(.96)	7.75(.50)	.5
Using a variety of assessment strategies	7.00(.00)	8.25(.96)	.04
Providing alternative explanations or example	6.75(.50)	8.25(.96)	.05
Implementing alternative teaching strategies	6.50(1.00)	8.25(.96)	.04
Entire Survey Average	7.23(.41)	7.89(.66)	.04

*Question was left unanswered by one participant.

New instructors also saw statistically significant change in their overall composite average score at the end of the innovation ($M=7.89$ $SD=.66$) vs pre-innovation scores ($M=7.23$, $SD=.41$; $t(3df)=-2.580$, $p=.04$).

Question 1b: Did T-SEDI Increase Instructor use of Constructivist Strategies?

Research question 1b was addressed through qualitative analysis of comments and researcher observations during the innovation CoP meetings.

CoP Meeting Data

Qualitative data for the CoP meetings were evaluated utilizing HypeRESEARCH. A codebook consisting of 8 a priori codes was utilized in the initial coding pass on the first CoP meeting from phase 1. That code book was expanded to include an additional 10 in-vivo codes from a second round of coding. This was used as the beginning codebook for evaluation of the CoP meetings. The final iteration of the codebook consisted of 8 a priori codes, 3 pattern codes, and 28 in-vivo codes.

Throughout the innovation, there appeared to be a shift away from a defensive stance regarding constructivist strategies to an acceptance of strategies. One participant who had some administrative responsibilities for one of the programs stated, “I would hope that none of my adjuncts would change the curriculum,” during the first meeting when discussing implementing PBL. The same participant said in the second meeting, when the group was asked if they had found a way to use PBL in the classroom, “Today! In just ½ hour we have a class, and it’s an extra class that we normally don’t have ... so we’ll see how it goes.” This change in position was echoed by others as the innovation continued. Where conversation was somewhat slow during first meetings and participants spent time looking around the room and waiting for someone else to participate, the second set of CoP meetings were livelier, and discussion was much more free flowing.

An additional insight that arose from session observations was the nature of conversation around the constructivist strategies. During early meetings, the discussion revolved around understanding new constructivist strategies in comparison with the strategies with which they were already familiar. For example, participants seemed to have a foundation in case-study learning and attempted to understand PBL by how it related to case-study learning. This was illustrated by the participant who offered “I was simply trying to figure out how it’s different than using cases.” To which another participant responded,

“I’m not sure that it is different, or it has to be different, ‘cause that’s what a case study is.”

Later discussions seemed to shift to not just understanding the strategies themselves but also how and when those strategies could be integrated into their teaching (immediately, or in the later process of course redesign). This motivation to include the strategies in teaching was clearly illustrated by one participant who said, “I did relate that I wondered if this could be applied to that in some way, to turn it into a bigger assignment or activity.” Participants in later sessions appeared to be more focused on looking for ways to implement the strategies being presented and were more collaborative in suggesting ways of using the strategies. One of the participants gave voice to that when they offered this:

But let me say, what I like about the group project, or the group learning is, you know, we’re trying to give them ... prepare them for the ... to go out and get jobs, right, and in ... at work you’re typically working on things with other people. And so you need to be able to [say] we gotta fix this. How are we going to do that? How can we do this together? And so, it’s a better simulation of what the workforce is like than solo assignments or tests.

Question 2: Most Effective Aspects of the T-SEDI Program

Data for question 2 came primarily from two questions on the post-innovation survey and were supplemented by information from the researcher’s journal. Two respondents indicated that they found the group discussions most useful whereas the remaining seven participants indicated that they found both the articles and the group discussions equally useful. One of the respondents augmented this answer by indicating more group discussions would be valuable, along with starting them earlier in the semester. Only one participant indicated that the articles themselves were of greatest value.

Outside of the innovation sessions, on four separate occasions, different participants approached me between classes at the college where the innovation took place. Each one indicated that they enjoyed the discussions that had taken place and hoped that they would prove useful. Two of the individuals indicated that they wished we could have more discussions like the ones that had been connected with the innovation. None of these individuals were the participant who had responded in the post-innovation survey about the discussions being the best aspect or more discussion time being a good addition to the

contribution, which suggests that the majority of the group felt that the discussions were the most useful aspect of the innovation.

Conclusions

Based on both the quantitative and qualitative data, there is evidence to suggest that the T-SEDI program had a positive impact in teachers expressed sense of TSE for the population of new instructors and that all instructors demonstrated an increase in comfort working with constructivist strategies as a result of the program

Discussion

The observed changes in TSE are consistent with the literature, which has shown that adjunct instructors are often asked to teach classes with little to no formal training regarding pedagogy, andragogy, or any other formal instruction regarding teaching strategies (Baik et. al., 2013; Maksymchuk, 2018). When little to nothing by way of foundational knowledge is provided at the beginning of an adjunct instructor's experience with teaching, anything provided during supplemental training will likely have the effect of increasing TSE.

When examined against the model of self-efficacy (Bandura, 1997), increased self-efficacy for new instructors was likely because opportunities were afforded for effective activity in several aspects of the self-efficacy domains. The articles provided critical information around the mastery tasks that would be necessary for effective implementation of the constructivist strategies discussed, even if the instructors had never experienced them prior to the innovation. CoP meetings provided verbal persuasion as to the importance of learning to effectively implement the strategies. Finally, the CoP meetings also provided an opportunity for vicarious experience as experienced instructors talked through ways that the strategies were applied, difficulties they experienced, and outcomes that were achieved.

Experienced instructors did not report the same increase in self-efficacy, and in fact there was one statistically significant drop in experienced instructors' feelings of their abilities to calm disruptive students. This negative direction of change was an unexpected outcome. It is possible that, because experienced instructors rated themselves high in TSE the outset of the process, their engagement in the CoP helped them discover weaknesses that they previously were unaware of. Increasing the TSE of experienced instructors would likely take much more time and training to significantly impact their higher TSE scores. Further, the focus of the CoP meetings might need to be augmented to include more specific TSE development activities focused on

experienced instructors, such as pairing them in a mentor/mentee relationship during the entire process (Morton, 2012; Paul, 2015; Baik et al, 2018).

With regard to the change in instructors stated use of constructivist strategies, this is also not surprising. The CoP meetings offered both vicarious experience and verbal persuasion from peers, this improvement in stated use of constructivist strategies in general, and of PBL specifically, is consistent with the findings in the literature that new instructors desire engagement with experienced instructors to help them know not only what is working well but how to integrate new approaches to their teaching. (Thirolf, 2012; Thirolf, 2013; Paul, 2015). As instructors were provided with a setting where new approaches could be discussed and others' experiences of using them were shared, they seemed more willing to try the new strategies.

With regard to which aspect of the innovation was most effective, the quantitative data suggest that both factors, articles and meetings, were seen to be valuable. However, because the option in the survey simply gave a forced choice option of "article 1, article 2, group discussion, all equal," it is likely that the default choice of "all equal" was selected as a way of saving time during the survey. The qualitative data from the meetings seems to suggest that participants referenced the articles, but the true value appears to have been in their discussions with others, where they could elaborate, check their own understanding, and learn from the experiences of one another. Comments from instructors outside of the meetings supported this idea of how valuable the peer-to-peer interaction in the meetings was with no mention of the articles. This is consistent with the literature (Morton, 2012; Baik et. al., 2013), which suggested that new faculty members' satisfaction and self-efficacy could be positively impacted by engaging them with experienced faculty in group and mentoring settings.

Limitations

Limitations for this AR study grew out of the study methods and protocol itself, including small sample size, a mixed population of experienced and novice instructors, imprecise measures, the lack of a second rater for qualitative data, and the limited time for the entire intervention.

Implications for Future Research and Practice

The T-SEDI program, in its limited scope in this study, still showed measurable improvement in TSE through the use of constructivist strategies. It is not unreasonable to consider how this program could

result in stronger gains if three factors were addressed, namely an expansion of time, scope, and meaningful connection with existing faculty. Future studies may see the positives of this study compounded if these factors could be built upon.

As for professional practice, the results of the study suggest that the CoP framework may provide a critical opportunity for experienced and well-prepared instructors to pass on information to newer and less well-prepared instructors in a successful manner. Colleges, universities, and even K-12 institutions might do well to investigate opportunities for staff to meet in CoP groups across and within disciplines to provide a wide range of opportunities for the enhancement of TSE among all staff members.

References

Baik, C., Naylor, R., & Corrin, L. (2018). Developing a framework for university-wide improvement in the training and support of ‘casual’ academics. *Journal of Higher Education Policy and Management* 2018, (40)4, 375–389. <https://doi.org/10.1080/1360080X.2018.1479948>.

Bandura, A. (1997). *Self-efficacy: The Exercise of Control*. New York: Freeman and Company.

Bautista, A.M., & Cipagauta, E.M. (2019). Didactic trends and perceived teachers’ training needs in higher education: a case study, *International Journal of Cognitive Research in Science, Engineering and Education*, 7(3), 71-85. <https://doi.org/10.5937/IJCRSEE1903071B>.

Derry, J. (2013). *Vygotsky: Philosophy and Education*. New York: John Wiley & Sons.

Flaherty, C. (2018, October 12). A non-tenure-track profession? *Insidehighered.com*. <https://www.insidehighered.com/news/2018/10/12/about-three-quarters-all-faculty-positions-are-tenure-track-according-new-aap>.

Klemenčič, M. (2020). Successful design of student-centered learning and instruction (SCLI) ecosystems in the European higher education area: A keynote at the XX Anniversary of the Bologna Process. https://www.laboratoriopermanentedidattica.it/wp-content/uploads/2020/02/02-keynote_KlemencicM.pdf.

Maksymchuk, I., Maksymchuk, B., Frytsiuk, V., Mtvichuk, T., Demchenko, I., Babii, I., Tsybal-Slatvinska, S., Nikitenko, A., Bilan, V., Sitovskyi, A., & Savchuk, I. (2018). Developing pedagogical mastery of future physical education teachers in higher education institutions. *Journal of Physical Education and Sport*, 18(2), 810-815. <https://doi.org/10.7752/jpes.2018.02119>.

Merriam, S.B., Cafferella, R.S., & Baumgartner, L.M. (2007). *Learning in Adulthood: A Comprehensive Guide*, 3rd edition. San Francisco: Jossey-Bass.

Merriam-Webster. (n.d.). Andragogy. In *Merriam-Webster.com*. Retrieved April 26, 2022, from <https://www.merriam-webster.com/dictionary/andragogy>.

Merriam-Webster. (n.d.). Pedagogy. In *Merriam-Webster.com*. Retrieved April 26, 2022, from <https://www.merriam-webster.com/dictionary/pedagogy>.

Mertler, C.A. (2020). *Action Research: Improving Schools and Empowering Educators*, 6th ed. Los Angeles: Sage Publishing.

Morton, D.R. (2012). Adjunct faculty embraced: The institution's responsibility. *Christian Education Journal*. 9(2), 396-405. <https://doi.org/10.1177/073989131200900211>.

Paul, P.A. (2015). Transition from novice adjunct to experienced associate degree nurse educator: A comparative qualitative approach. *Teaching and Learning in Nursing*, 10(1), 3-11. <https://doi.org/10.1016/j.teln.2014.09.001>

Plano Clark, V.L., & Creswell, J.W. (2015). *Understanding Research: A Consumer's Guide*, 2nd edition. Boston: Pearson Education.

Roehl, A., Reddy, S.L., & Shannon, G.J. (2013). The flipped classroom: An opportunity to engage millennial students through active learning strategies. *Journal of Family and Consumer Sciences*, 105(2), 44-49

Shattuck, J., Dubins, B., & Zilberman, D. (2011). MarylandOnline's inter-institutional project to train higher education adjunct faculty to teach online. *International Review of Research in Open and Distance Learning*, 12(2), 40-62. <https://doi.org/10.19173/irrodl.v12i2.933>.

Smith, M.K. (2002). Malcolm Knowles, informal adult education, self-direction, and andragogy. *The Encyclopedia of Pedagogy and Informal Education*. <https://www.infed.org/thinkers/et-knowl.htm>.

Sutton, R.I., & Rao, H. (2016). *Scaling Up Excellence: Getting to More Without Settling for Less*. London: Random House Business Books.

Thirolf, K.Q. (2012). The faculty identities of community college adjuncts teaching in the humanities: a discourse analysis study. *Community College Journal of Research and Practice*, (36)4, 269-278. <https://doi.org/10.1080/10668926.2012.637864>.

Thirolf, K.Q. (2013). How faculty identity discourses of community college part-time faculty change over time. *Community College Journal of Research and Practice* (37)3, 177-184. <https://doi.org/10.1080/10668926.2013.739511>.

Tschannen-Moran, M., & Woolfolk Hoy, A.W. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, 17(7), 783-805. [https://doi.org/10.1016/S0742-051X\(01\)00036-1](https://doi.org/10.1016/S0742-051X(01)00036-1).

University of Buffalo Curriculum, Assessment and Teaching Transformation. (n.d.). *Constructivism*. Retrieved April 26, 2022, from <https://www.buffalo.edu/catt/develop/theory/constructivism.html>.

Wenger-Trayner, E., & Wenger-Trayner, B. (2015). Introduction to communities of practice: A brief overview of the concept and its uses. Retrieved April 26, 2022, from <https://wenger-trayner.com/introduction-to-communities-of-practice/>.

Wicks, J.M., Greenhow, C.M., & Tyler, A.J. (2020). Adjunct faculty onboarding: Is social media a solution? *Community College Journal of Research and Practice*, 44(7), 544-548. <https://doi.org/10.1080/10668926.2019.1616007>.

Will, M. (2022, June 15). Paraprofessionals: As the ‘backbones’ of the classroom, they get low pay, little support. *Edweek.org*. <https://www.edweek.org/leadership/paraprofessionals-as-the-backbones-of-the-classroom-they-get-low-pay-little-support/2022/06>.

Plane Wall Thermal Radiation Shielding

Tori Thomas, MaryJo Taylor, Michael Forbes, Ali Siahpush

Southern Utah University

ABSTRACT

This experiment modeled thermal radiation shielding by using a thin aluminum plate as a radiation shield. The shield was placed parallel between two thin aluminum plates with aligned centers. A heating source was placed on the back side of one plate to produce a constant heat flux, and 2-inch insulation was placed on the back side of the heating source to minimize the heat transfer to the ambient surroundings. The entire system was then placed inside a vacuum chamber to minimize the effects of natural convection heat transfer. Once a vacuum pressure of -19" Hg was attained, the system was first tested without a shield between the two thin plates of a heated aluminum plate and the other aluminum plate. The temperatures of each of these plates were recorded until the test system reached steady state. This same experiment was replicated with the same size plates placed between the two plates, and the temperatures of all three plates were recorded until the system reached steady state. By using the theoretical heat transfer rate from the heating source, the measured temperature of the back plate was calculated. These predicted temperatures were compared with the measured temperatures. The

results of this experiment are discussed in terms of the effectiveness of using a thin aluminum plate as a radiation shield.

INTRODUCTION

Thermal radiation shields are used to reduce heat transfer and are used in several different apparatuses and engineering systems. It is important to understand which materials are effective as thermal radiation shields [1]. The motivation of this undergraduate research experiment was to enhance a previous apparatus to evaluate the effectiveness of an aluminum plate as a thermal radiation shield. The first iterations of the apparatus were unsuccessful because the experiment was conducted in atmospheric pressure with the presence of natural convection heat transfer, which was a major factor in the previous system's failure. For this experiment to succeed, the apparatus was tested inside a vacuum chamber to eliminate natural convection heat transfer.

When looking for vacuum chambers, several factors were considered. The chamber needed to be large enough to enclose our system, to allow for thermocouples and power lines to run through the system, and to maintain a vacuum to eliminate convection. Many vacuum chambers were found that had these capabilities including companies that were willing to make an insert for power and thermocouples wires to exit the chamber (Appendix). These options were not viable in this experiment because of budgetary and size constraints. Considering the cost of a vacuum chamber, it was decided to decrease the size of the apparatus and design and build an insert to allow for thermocouples and power lines to enter the vacuum chamber. This insert was made using a CNC lathe, and the integrity of the seal was maintained by using room-temperature vulcanizing silicone [2].

THEORY

Thermal radiation is the electromagnetic energy emitted from matter [1]. This energy affects the surroundings based on several factors, including distance, surface properties, and view factors. Natural convection heat transfer is ignored because the experiment was performed in a vacuum [1].

Consider a system of two square plates facing each other in parallel; expressions W_i and W_j involving their dimensions can be defined as [1, p. 772]

$$W_i = \frac{w_i}{L}; W_j = \frac{w_j}{L} \quad (1)$$

where w_i is the width of plate i (m), w_j is the width of plate j (m), and L is the distance between the plates (m). Note that all plates have the same dimensions and their heights and widths are the same. These dimensions can be used to express the view factor as [1, p. 772].

$$F_{i-j} = \frac{[(W_i + W_j)^2 + 4]^{1/2} - [(W_j - W_i)^2 + 4]^{1/2}}{2W_i} \quad (2)$$

where F_{i-j} is the view factor from plate i to plate j . In cases where the two plates are close, $L \ll W_i$, Eq. (3) is simplified and can be used to determine the view factor of parallel plates. Heat transfer by thermal radiation between these two surfaces may be expressed by [1, p. 785].

$$\dot{Q}_{12} = \frac{\sigma(T_1^4 - T_2^4)}{R_{tot}} \quad (3)$$

where \dot{Q}_{12} is the rate of heat transfer (W) from surface 1 to surface 2, σ is the Boltzmann's constant ($5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$), T_1 is the temperature of the first surface (K), T_2 is the temperature of the second surface (K), and R_{tot} is the total thermal resistance ($1/\text{m}^2$).

The total thermal resistance for radiation heat transfer is the sum of the surface resistance and space resistance. The total resistance of radiation heat transfer from surface 1 to surface 2 with the same emissivity and surface area becomes [1, p. 788].

$$R_{tot} = \frac{1}{A} \left(\frac{2(1 - \varepsilon)}{\varepsilon} + \frac{1}{F_{12}} \right) \quad (4)$$

Substituting Eq. (8) into Eq. (4) results in a heat transfer between two surfaces as

$$\dot{Q}_{12} = \frac{A_1 \sigma (T_1^4 - T_2^4)}{\left(\frac{2(1 - \varepsilon)}{\varepsilon} + \frac{1}{F_{12}} \right)} \quad (5)$$

From Eq. (5), if the temperature of the first plate (T_1) and the heat transfer rate from the heating pad (\dot{Q}_{12}) are known, the temperature of the second surface (T_2) can be calculated from Eq. (5).

Consider the radiation shield case where heat transfer is by radiation from surface 1 to surface 3 (shield), and surface 2 (Fig. 1).

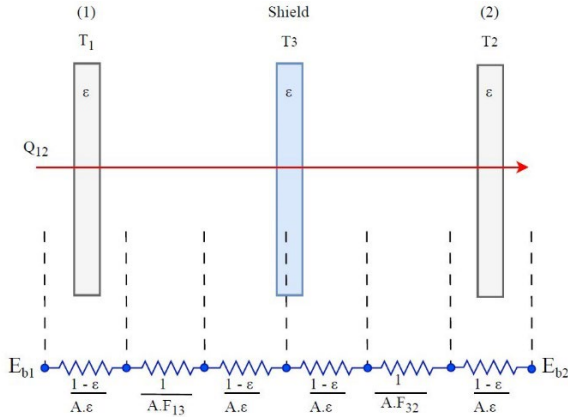


Figure 3. Radiation shielding configuration.

Note that the plates have the same surface area, spacing, surface conditions, and $F_{13} = F_{23} = F_{12}$ of non-shielding, then R_{tot} becomes

$$R_{tot} = \frac{1}{A} \left(\frac{4(1 - \epsilon_{al})}{\epsilon_{al}} + \frac{2}{F_{12}} \right) \quad (6)$$

Substituting Eq. (6) into Eq. (4), yields

$$\dot{Q}_{12} = \frac{A\sigma(T_1^4 - T_2^4)}{\left(\frac{4(1 - \epsilon_{al})}{\epsilon_{al}} + \frac{2}{F_{12}} \right)} \quad (7)$$

If the temperature of the first plate (T_1) and the heat transfer rate from the heating pad (\dot{Q}_{12}) are known, the temperature of the second surface (T_2) can be calculated from Eq. (5).

Applying the first law of thermodynamics, the amount of heat that is directed to the aluminum plates from the heating pad is equal to the heat stored in the plate as

$$\dot{Q}_{12} = mcp \frac{\Delta T}{\Delta t} \quad (8)$$

where \dot{Q}_{12} is the rate of heat transfer from the heating pad to the aluminum plates (W), m is the mass of one aluminum sheet (kg), cp is the specific heat of the aluminum plate ($J/kg \cdot K$), ΔT is the temperature difference of the aluminum plate ($^{\circ}C$), and Δt is the time it took for the aluminum plate to reach steady (s).

MATERIALS AND PROCEDURE

Figure 2 shows the second iteration of the testing apparatus. This apparatus is sized down to enclose 8×8 -in aluminum metal plates compared with the 16×16 -in size used in the first iteration. Table 1 presents the parts required for the construction of the testing apparatus and experimental setup. For experimental testing, the apparatus is placed inside a vacuum chamber as shown in Figure 3.

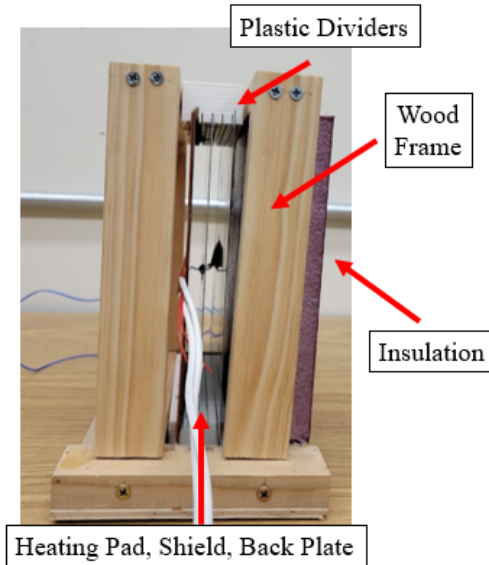


Figure 4. Second iteration of the testing apparatus.

Table 1. Parts used for testing apparatus and experimental setup
Four K-type thermocouples [3]
S220-T8 data logger [4]
8×8 -in heating pad [5]
Three 8×8 -in by 0.04-in-thick aluminum plate ($\epsilon=0.09$) [6]
Two 8×8 -in by 1-in-thick foam insulation blocks [7]
Wood frame
0.5-in-thick plastic spacers
Eventek KPS3010D DC power supply
15-gallon aluminum vacuum chamber [8]
V9D 9CFM two-stage vacuum pump kit [8]
Permatex 81724 multipurpose RTV silicone gasket maker [2]

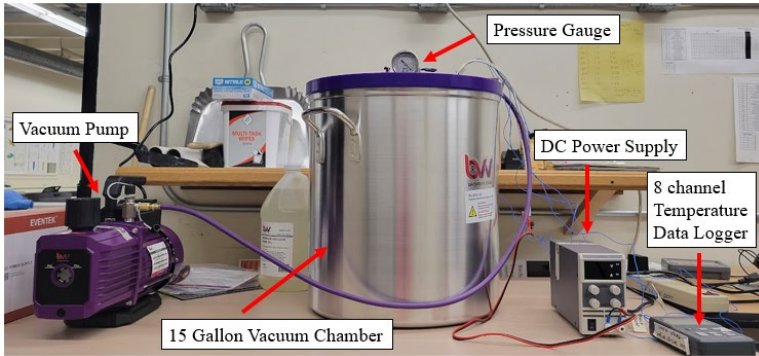


Figure 5. Experimental setup for testing of the second iteration.

The procedure for the experiment is as follows:

1. Place the experimental setup inside the vacuum chamber.
2. Connect the power lines to the DC power supply and turn the voltage to 3V.
3. Turn the pump on to the maximum vacuum pressure of -19 inHg that appears on the pressure gauge and repeat every 10 minutes throughout the experiment to maintain the vacuum pressure.
4. Record the temperature of each thermocouple every 10 minutes until steady state is attained.

The experimental steps were performed twice, once with no shield in place and the other time with a radiation shield in place.

RESULTS AND DISCUSSION

To determine the theoretical temperature values, the resistance of the experiment and heat transfer rate from the heat pad need to be evaluated. To find the resistance of the experiment, the space resistance must first be found. The space resistance can be evaluated using the view factor from the plates by using Eqs. (1) and (2). In the experiment with the shield, it was determined that the view factor was 0.94 between the plates, because all of the plates were equally spaced 0.0127 m apart. As expected, the view factor was 0.94 for the experiment without the shield because the back plate was moved forward, to 0.0127 m away from the heat pad, to maintain a constant view factor throughout the entire experiment.

Next, the surface resistance evaluation was considered. The surface resistance depends on the emissivity of the aluminum plates. For this

experiment, it was determined that for a commercial aluminum plate, the emissivity value is 0.09 [9]. The total resistance of the experiment was the sum of the space resistance and surface resistance together. The total resistance for the experiment with no shield is shown in Eq. (4) and that with the shield is shown in Eq. (6).

To find the heat transfer rate from the heating pad, Eq. (8) was used. The results for the heat transfer rates are shown in Table 2. After the values for resistance and heat transfer rate are obtained, the temperature of the back plate can then be calculated. Equation (3) is used to predict the temperature of the back plate, then substituted into Eq. (5) without the shield and Eq. (7) with the shield.

Table 2. Theoretical values for the heat transfer from the heating pad					
	m (kg)	C_p ($\frac{J}{kg \cdot K}$)	ΔT (°C)	Δt (s)	\dot{Q} (W)
No shield	0.082	887	32.9	9000	0.266
Shield	0.082	887	26	7200	0.263

The experimental results closely matched the theoretical values, as the difference for the experiment was 0.02°C without the shield and 1.17°C with the shield. Table 3 shows the results, and the temperatures throughout the experiments are presented in Figures 4 and 5.

Table 3. Experimental vs. theoretical temperatures of the back plate							
No Shield				Shield			
	Experimental		Theory	Experimental			Theory
	Heat pad	Back plate	Backplate	Heat pad	Shield	Back plate	Backplate
Final (°C)	71.6	55.7	55.68	72.0	47.1	40.2	39.03

During analysis, it was realized that the experiment with the shield reached steady state faster than the experiment without a shield. This occurs because the back plate and shield do not have to reach as high of a temperature as in the experiment without the shield. Another factor for the steady state occurring earlier is the heat pad reaching its steady state temperature faster. More heat is reflected to the heat pad from the presence of two aluminum plates instead of one. In the experiment with the shield, the back plate took noticeably longer to begin increasing in temperature. This is a direct result of the shield being implemented into

the experiment because, with the shield in place, it takes longer for the heat to reach the back plate.

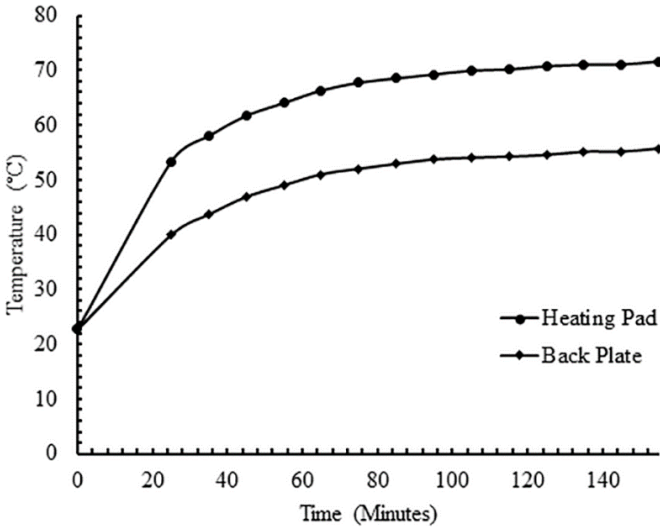


Figure 6. Experimental results with no shield.

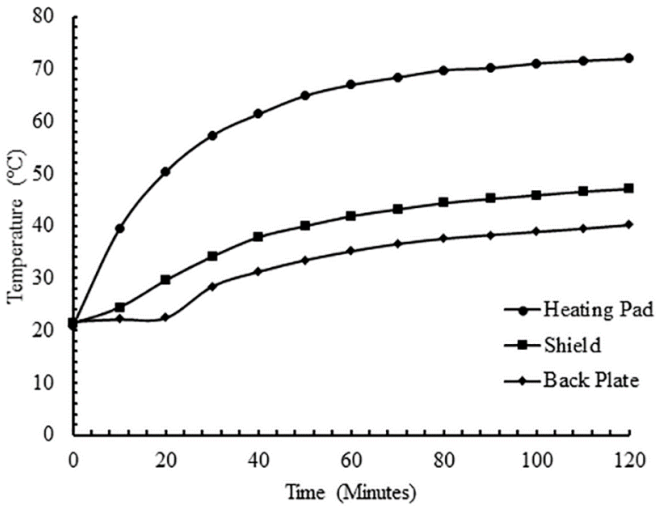


Figure 7. Experimental results with a shield.

It was expected that the temperature of the shield would be different than the temperature of the back plate in the experiment without the shield, even though they are the same distance from the heat pad. In the experiment without the shield, the back plate would experience insulated heat because there is no plate behind it, whereas in the experiment with the shield, the shield would not experience this insulated heat because there is a plate behind the shield. This would cause the backplate in the experiment with the shield to reach a higher temperature.

The use of an aluminum plate as a plane wall thermal radiation shield was effective. The results showed a significant decrease in the temperature in the back plate and the theoretical values support the data that was obtained by experimentation. This also proves that the method that was used to obtain the theoretical data was a valid method to predict the temperature of the back plate.

SOURCES OF ERROR

Throughout experimentation, several sources of errors were discovered. One of these errors was the vacuum chamber not holding a constant vacuum. Because the pump was limited to the maximum vacuum pressure of -19 inHg, the chamber very slowly lost some vacuum pressure. To reduce this error, the pump was turned on every 10 minutes to maintain a constant pressure of -19 inHg in the vacuum. One reason the loss of pressure could have occurred was the installation of the insert into the system. Although every precaution was taken to ensure an extremely tight seal, some air could have escaped through the gasket. Another reason the system could have lost pressure is outgassing and the lid not being fully straight and centered. If the lid is not fully straight and centered, then it allows a small space for the air to enter the chamber. The accuracy of our pressure gauge is another possible source of error, and this error could be minimized by replacing it with a digital one.

CONCLUSION AND RECOMMENDATIONS

The purpose of this experiment was to evaluate the effectiveness of an aluminum plate as a thermal radiation shield. As a result, a second apparatus was built to fit inside a vacuum chamber. This eliminates heat transfer through natural convection.

Two experiments were performed to analyze the effectiveness of aluminum plates by evaluating the temperature of the back plate in the experiment: the first with no shield in place and the second with a shield in place to reduce the heat emitted from the heating pad. The temperatures of the back plate were theoretically predicted by using the amount of heat directed to the aluminum sheets. Next, the temperatures

from each experiment were determined. With the shield in place, the temperature of the back plate decreased by 15.5°C. The experimental and theoretical temperatures were compared and the theoretical temperatures closely match the experimental values. Overall, the experimental and theoretical evaluations of the effectiveness of a thermal radiation shield demonstrated that the shield was indeed effective because the temperature of the back plate decreased.

To improve how well the vacuum chamber maintains the vacuum pressure, these changes should be implemented: buying a better sealant for the insert, placing a plug on the connection output, and ensuring the lid is fully centered to prevent outgassing. Similarly, a digital pressure gauge should be implemented to ensure the exact vacuum pressure maintained in the vacuum. These changes will increase the consistency and accuracy of the results.

ACKNOWLEDGMENTS

This project would not have been possible without the help and support of the Department of Engineering and Technology at Southern Utah University. Their contributions included providing the equipment and assistance from faculty. Also, the undergraduate research funding was partially provided by the NASA Utah Space Grant Consortia.

REFERENCES

1. Cengel, YA., and Ghajar, AJ. (2015) Heat and Mass Transfer: Fundamentals & Applications, Fifth Edition, McGraw-Hill, NY.
2. “Permatex 81724 Ultra Blue Multipurpose RTV Silicone Gasket Maker–3.35 oz Tube (77B) (1).” Amazon.com. Updated 2023. Retrieved January 30, 2023, from https://www.amazon.com/Permatex-%C2%AE-Multipurpose-Silicone-Gasket/dp/B000I14QVA/ref=sr_1_2?keywords=Permatex-81724&qid=1675094658&sr=8-2
3. “K-Type Thermocouple-ATB1 Bead Type Thermocouple-ATB1.” TruTech Tools, Ltd. Updated 2023. Retrieved November 11, 2022, from https://www.trutechtools.com/ATB1?utm_source=google&utm_medium=surfaces&utm_campaign=shopping+feed&utm_content=free+google+shopping+clicks&gclid=Cj0KCQjwwfiaBhC7ARIsAGvcPe4HL4aKeHez1StVCbsEF1JHJIhc5TsXBreVXEdr88IfsJM4NwAV2k4aAo3vEALw_wcB.

4. “S220-T8 Multi-channel Handheld Thermocouple Temperature Data Logger.” Huato Retrieved February 21, 2022, from <https://www.huato.cn/product/s220-t8-multi-channel-handheld-thermocouple-temperature-data-logger/>
5. “200 x 200 mm (8" x 8"), 12V 200W, with 3M PSA & NTC 100K thermistor, KEENOVO Silicone Heater Mat/Pad, 3D Printer HeatBed.” Amazon.com. Retrieved November, 11, 2022 from <https://www.amazon.com/thermistor-KEENOVO-Silicone-Printer-HeatBed/dp/B011U6QCOA>
6. “Table of Emissivity of Various Surfaces.” Transmetra Retrieved February 21, 2022, from https://www.transmetra.ch/images/transmetra_pdf/publikationen_literatur/pyrometrie-thermografie/emissivitaet_table.pdf
7. “DC Power Supply Adjustable (30V 10A), Eventek Variable Switching Regulated Digital Power Supply with Alligator Leads US Power Cord (30V 10A).” Amazon.com. Retrieved November 11, 2022, from https://www.amazon.com/Adjustable-Eventek-KP-S3010D-Switching-Regulated/dp/B073TW8H2S/ref=asc_df_B073TW8H2S/?tag=hyprod20&linkCode=df0&hvadid=252589173590&hvpos=&hvnetw=g&hvrnd=765296224937054370&hvpone=&hvpstwo=&hvqmt=&hvdev=c&hvdvcmld=&hvlocint=&hvlocp
8. “Best Value Vacs 15 Gallon Aluminum Vacuum Chamber and V9D 9CFM Two Stage Vacuum Pump Kit.” Building Vision and Variety. Updated 2022. Retrieved January 18, 2023 from <https://shopbv.com/products/best-value-vacs-15-gallon-aluminum-vacuum-chamber-and-v9d-9cfm-two-stage-vacuum-pump-kit>
9. “Table of Emissivity of Various Surfaces.” Transmetra. Retrieved February 21 2022, from https://www.transmetra.ch/images/transmetra_pdf/publikationen_literatur/pyrometrie-thermografie/emissivitaet_table.pdf

Appendix

This appendix provides the list of vacuum chambers companies that were willing to make an insert for power and thermocouples wires to exit the chamber.

Vacuums with required capabilities		
Product Name	Company	URL
Bel-Art F42400-4001 Lab Companion clear polycarbonate vacuum desiccator cabinet, 11 liter	Global Industrial	Updated 2023. Retrieved January 4, 2023, from https://www.globalindustrial.com/p/f42400-4001-lab-companion-clear-polycarbonate-vacuum-desiccator-cabinet-11-liter?infoParam.campaignId=T9F&gclid=Cj0KCQiA5NSdBhDfARIsALzs2EBekYNxD-lCa6zRVXv99ucVs2mMx3CcpOLJPMLTfbp56mj4C85W8AYaAkySEALw_wcB
Bel-Art F42029-0000 Techni-Dome® polycarbonate vacuum desiccator (1 gas port), 2.3 cu. ft.	Global Industrial	Updated 2023. Retrieved January 4, 2023 from https://www.globalindustrial.com/p/f42029-0000-polycarbonate-vacuum-desiccator-1-gas-port-23-cu-ft?infoParam.campaignId=T9F&gclid=Cj0KCQiA5NSdBhDfARIsALzs2EAV6LS23SEKd0pt9Sri6-zRhwiKsOVr7qyrbgXD_IOqzAOomjn6xb0aAnppEALw_wcB
Bel-Art Space Saver polycarbonate vacuum desiccator 420250000, 0.31 cu. ft., white bottom, 1/PK.	Global Industrial	Updated 2023. Retrieved January 4, 2023 from https://www.globalindustrial.com/p/420250000-vacuum-desiccator-pc-pp-230mm-plate-white-base?infoParam.campaignId=T9F&gclid=Cj0KCQiA5NSdBhDfARIsALzs2ECtr8ct4Bnh-Trk00Pw5gPPT4MeAZBIpE0_SIVeLVrViKHjMDYculIaAt6ZEALw_wcB

Desiccator, Vacuum, clear base, polycarbonate top and base, 300mm ID, with desiccator plate	Southern Labware	Updated 2020. Retrieved January 4, 2023 from https://www.southernlabware.com/desiccator-vacuum-clear-base-polycarbonate-top-and-base-300mm-id-with-desiccator-plate.html?gclid=Cj0KCCQiA5NSdBhDfARIsALzs2EATdCniCeskWIYzkOr7zW25YwepkFDjq8Rba0EHrHRoskLnAyE50oaAkS6EALw_wcB
Chamber vacuum packaging sealing machine 11-1/2" seal bar and oil pump	Toolots	Updated 2022. Retrieved January 4, 2023 from https://www.toolots.com/ng-frontend/productDetail?id=28605&title=Chamber%20Vacuum%20Packaging%20Sealing%20Machine%2011-1/2%22%20Seal%20Bar%20and%20Oil%20Pump&gclid=Cj0KCCQiA5NSdBhDfARIsALzs2EDMfk0Uc-hEH4xrKrZMExKUCnFx-UBRyDM2pr5Of5xZe3l0KsUes0aAv8VEALw_wcB
Chamber vacuum packing machine with 11-13/16" seal bar	Toolots	Updated 2022. Retrieved January 4, 2023 from https://www.toolots.com/ng-frontend/productDetail?id=65609&title=Chamber%20Vacuum%20Packaging%20Machine%20With%2011-13/16%22%20Seal%20Bar&gclid=Cj0KCCQiA5NSdBhDfARIsALzs2EAznwQqdvYnJf-NoX-rBla3ny0gHvWDBIUTNkxjiNfGDMMOA-CG2caAobHEALw_wcB
Borsoil® glass desiccator vacuum, Stopcock with PTFE spindle and porcelain plate, 250 mm	Southern Labware	Updated 2020. Retrieved January 4, 2023 from https://www.southernlabware.com/borsoilr-glass-desiccator-vacuum-stopcock-with-ptfe-spindle-and-porcelain-plate-250-mm.html?gclid=Cj0KCCQiA5NSdBhDfARIsALzs2ECvqeKLDUjHh4lVgRHjdFPi5zL9sCwKA5XbOY0bgy4xSTPJrcSLu0aApx4EALw_wcB

3.3 gallon square 11/16" acrylic wall vacuum chamber	Building Vision and Variety	Updated 2022. Retrieved January 10, 2023 from https://shopbv.com/products/3-3-gallon-square-3-4-acrylic-wall-vacuum-chamber?variant=32490795434080&utm_medium=cpc&utm_source=google&utm_campaign=Google%20Shopping&gclid=Cj0KCQiAtvSdBhD0ARIsAPf8oNk2ZZ-hUHmzvXamo2JFLd9p9i9ujggldhZ_ewjJOxZqPN4_mU5H-IaAnyfEALw_wcB
Best Value Vacs 5 gallon aluminum vacuum chamber and vacuum pump kit	Building Vision and Variety	Updated 2022. Retrieved January 18, 2023 from https://shopbv.com/collections/chamber-and-pump-kits/products/best-value-vacs-5-gallon-aluminum-vacuum-chamber-and-v4d-4cfm-two-stage-vacuum-pump-kit
Best Value Vacs 7 gallon aluminum vacuum chamber and V9D 9CFM two stage vacuum pump kit	Building Vision and Variety	Updated 2022. Retrieved January 18, 2023 from https://shopbv.com/collections/chamber-and-pump-kits/products/best-value-vacs-7-gallon-aluminum-vacuum-chamber-and-v7s-7cfm-single-stage-vacuum-pump-kit
VEVOR Vacuum Pump 7 CFM 3/4HP Dual stages air conditioning vacuum pump 2stage with 5 gallon vacuum chamber ultimate vacuum manifold gauge set, manifold gauge and hose for air conditioning systems	Vevor	Updated 2023. Retrieved January 10, 2023 from https://www.vevor.com/vacuum-pump-c11109/5-gallon-vacuum-chamber-7cfm-vacuum-pump-2-stage-air-conditioning-rotary-3-4hp-p_010820235428?utm_source=google&utm_campaign=19181904124&utm_term=144267773997&gclid=Cj0KCQiAtvSdBhD0ARIsAPf8oNlcEBIBUCevp9QbzTuEYg49t9En4NHwegYHm-WAkYd_132FJ87h0KYaAiUdEALw_wcB&v_tag=5b6cd231-9146-11ed-b813-a30777e747fe.1

Vacuums available for customization		
Product Name	Company	URL
Electrical wire vacuum feedthrough installation	Sanatron	Updated 2022. Retrieved January 4, 2023, from https://www.sanatron.com/clear-acrylic-vacuum-chamber-custom-options/electrical-wire-vacuum-feedthrough-installation.php
Vacuum chamber	MoonRanger	Updated 2023. Retrieved January 4, 2023, from https://labs.ri.cmu.edu/moonranger/vacuum-chamber/#:~:text=In%20order%20to%20decrease%20convective,5E%2D4%20Torr%20or%20less
How does heat get transferred in vacuum?	BYJU'S	Updated 2022 Retrieved January 9, 2023, from https://byjus.com/question-answer/who-does-heat-get-transferred-in-vacuum/
Heater and thermocouple feedthrough assembly	Belilove Company-Engineers	Retrieved January 16, 2023 from https://belilove.com/article_228_Heater-and-Thermocouple-Feedthrough-Assembly.cfm
Thermocouple feedthrough	RHSeals	Updated 2023. Retrieved January 16, 2023, from https://www.rhseals.com/thermocouple-vacuum-feedthrough/
Thermocouple vacuum feedthroughs	Sanatron	Updated 2022. Retrieved January 16, 2023, from https://www.sanatron.com/thermocouple-vacuum-feedthroughs.php
Acrylic vacuum chamber, cube, 10" inside dimensions, top load model, clamping lid	Sanatron	Updated 2022. Retrieved January 16, 2023, from https://www.sanatron.com/products/COO-ACVSB-101010/acrylic-vacuum-chamber-cube-10-inch-inside-dimensions-top-load-model-clamping-lid.php
Add vacuum thermocouple feedthroughs to your chamber	Sanatron	Updated 2022. Retrieved January 16, 2023, from https://www.sanatron.com/clear-acrylic-vacuum-chamber-custom-options/add-vacuum-thermo-couple-feed-throughs-to-your-chamber.php

Natural Convection Over A Heated Vertical Plate

Drew Hatch, Jordan Peterson, Braeden Brown, Jordan Katnik, Ali Siahpush
Southern Utah University

ABSTRACT

This experiment investigates natural convection over a heated vertical plate using experimental measurements and imaging techniques. A thin aluminum plate (8 in long by 8 in wide) is in contact with a constant heat flux (30W) heat source, heating the aluminum plate to approximately 70°C at the center of the plate. Thermocouples were attached to a horizontal rod at 1/8-in (0.3175-cm) intervals, and the rod was raised to different positions along the plate to measure temperatures in the boundary layer. Measured air temperatures showed the boundary layer was approximately one inch (2.54 cm) thick at the top of the plate. Schlieren imaging showed the laminar boundary layer with a maximum thickness of 0.5 in (1.275 cm). Calculations verified the laminar flow and provided further flow characteristics. Findings were summarized and compared with those from previous experiments to determine the behavior of natural convection over a heated vertical plate. Both experimentation and imaging showed the expected shape and flow characteristics of the natural convection boundary layer.

INTRODUCTION

Convection is the transfer of heat due to currents of a moving fluid. Natural convection (also called free convection) is a heat transfer where the motion of currents within the fluid is not forced by an external source. In the natural convection (NC) heat transfer, the flow is governed by buoyancy within the fluid and the difference in temperature between a surface and the ambient fluid temperature. When heat is transferred from a hot surface to the fluid, the temperature of the fluid increases and its density decreases. The buoyancy forces then cause the less dense fluid to rise. Alternatively, if the fluid is cooled, its density increases, causing the fluid to sink. The moving fluid is replaced by nearby fluid, creating a circulating current with the hotter fluid rising and the cooler fluid sinking [1].

Natural convection occurs in many everyday situations, such as cooking [2], air currents around a radiator [3], and the movement of magma in the Earth's mantle [3]. It is also an important factor in many engineering applications, such as heat exchangers [4], solar water heating [5], cooling of electronic devices [6], and building ventilation systems [7]. Many mechanical and industrial applications also involve temperature gradients between objects and the surrounding environment, leading to a similar phenomenon. With its wide range of applications and importance in the study of heat transfer, it is necessary to understand and analyze natural convection.

A previous experiment conducted at Central Washington University (CWU) [8] measured the thermal boundary layer thickness as well as the heat transfer coefficient of a hot vertical plate. A thermocouple (TC) was moved in precise increments to measure the air temperature. Once the measured air temperature was within 2°F of the ambient temperature, the distance from the plate was recorded as the thermal boundary layer thickness. The previous experiment was able to measure the thermal boundary layer thickness and calculate the corresponding heat transfer coefficient. However, only a single TC was used, and various experimental values were unclear and not defined in detail.

The objective of this experiment was to improve the CWU experiment by measuring the thermal boundary layer thickness using two methods. The first technique employed multiple TCs to experimentally measure the thermal boundary layer thickness and the second method will use imaging techniques to visually measure the thickness. These two methods will also be used to verify the expected shape of the thermal boundary layer. The aim of this experiment is to validate and improve upon the results of the CWU experiment by designing and constructing

an apparatus to measure the thermal boundary layer thickness of a vertical aluminum plate exposed to a constant heat flux. The Schlieren imaging technique will be used to visually measure the thickness. Using two methods will offer more complete and verifiable results in the absence of accurate theoretical predictions for the thermal boundary layer thickness.

THEORY

TC Experiment

For a vertical plate, the thermal boundary layer is the region of flow next to the plate in which the temperature effects are observed. The boundary layer is definite for steady-state laminar flow, with a parabolic shape as shown in Figure 1. For the fluid in contact with the vertical plate, the temperature of the air is the same as the plate surface. As the distance from the plate increases, the air temperature approaches room temperature. This temperature profile is presented in Figure 1.

The rate of heat transfer due to natural convection is determined by the temperature difference between the fluid and the hot surface, the fluid density and viscosity, and the geometry of the system [9]. The heat transfer coefficient, h ($\text{W}/\text{m}^2\cdot\text{K}$), affects the rate of convection heat transfer. For a vertical plate, this value can be calculated using two approaches. Heat flux (W/m^2) is defined as [1, p. 541]:

$$\dot{q} = h(T_s - T_\infty) \quad (1)$$

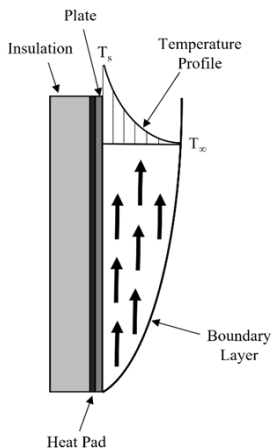


Figure 1 Thermal boundary layer profile along a vertical heated plate.

where T_s is the surface temperature of the plate (K) and T_∞ is the ambient temperature (K). When the heat flux and temperatures are known, h can be calculated. Another approach involves the Nusselt number, which is defined as [1, p. 541]:

$$Nu = \frac{hL}{k} \quad (2)$$

where L is the characteristic length of the plate (m) and k is the thermal conductivity ($\text{W}/\text{m}^2 \cdot \text{K}$). For a vertical plate, the characteristic length is the height of the plate. The Nusselt number is also expressed as [1, p. 542]:

$$Nu = \left\{ 825 + \frac{.387Ra^{\frac{1}{6}}}{\left[1 + \left(\frac{.492}{Pr} \right)^{\frac{9}{16}} \right]^{\frac{8}{27}}} \right\}^2 \quad (3)$$

where Ra is Rayleigh's number, and Pr is Prandtl number. Rayleigh's number is defined as [1, p. 542]:

$$Ra = \frac{g\beta(T_s - T_\infty)L^3}{\nu^2} Pr \quad (4)$$

where g is the gravitational constant (m/s^2), β is the coefficient of thermal expansion of the fluid ($1/\text{K}$) and ν is the kinematic viscosity of the fluid (m^2/s). Note that these properties are evaluated at the film temperature [1, p. 541]. It should also be noted that substituting Eq. (4) into Eq. (2) yields the h value.

The Grashof number determines whether the flow is laminar or turbulent, as shown in Figure 2. If Gr is less than 10^9 , the flow is laminar. The Grashof number is expressed as [1, p. 542]:

$$Gr = \frac{g\beta(T_s - T_\infty)L^3}{\nu^2} \quad (5)$$

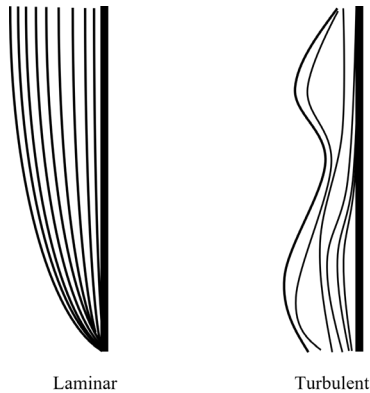


Figure 2 . Thermal boundary layer for laminar and turbulent flow.

Schlieren Imaging

Schlieren imaging is an optical technique used to visualize changes in the density of a fluid due to temperature or pressure variations. Light bends differently when the refractive index changes; therefore, a detector such as a camera can capture the light bending with a Schlieren technique [10]. Light from a source such as a flashlight is passed through a pinhole to create a collimated light beam (a light beam that does not disperse as it travels). A concave mirror will reflect and focus the beam of light to a point some distance away. A knife edge or razor blade is placed at this focal point so that the focused point of light is directly on the edge of the blade. A camera is placed behind the knife edge or razor blade, which controls the amount of light that reaches the camera to increase the contrast in the image [11]. The test object is placed in front of the mirror so that the reflected light passes through the test area on its way to the camera. As the light passes through the test area, it will refract differently through different densities, which is seen by the camera. A diagram of a simple Schlieren set-up is shown in Fig. 3.

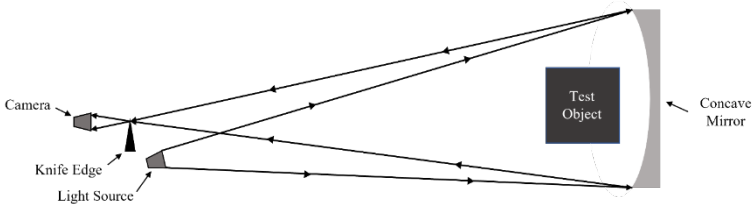


Figure 3. Schlieren imaging technique.

Schlieren imaging has many applications in fluid mechanics, including the study of shock waves, turbulence, and heat transfer via convection [12]. It can be used to visualize density gradients in natural convection, which causes the movement of the air. Any region of air that appears in the Schlieren image is inside the thermal boundary layer since it is hotter and less dense than the surrounding air.

The full list of materials and the experimental procedure are presented in Appendix A and B, respectively. The final experimental set-up is shown in Figure 4. Schlieren images were taken with this set-up as well.

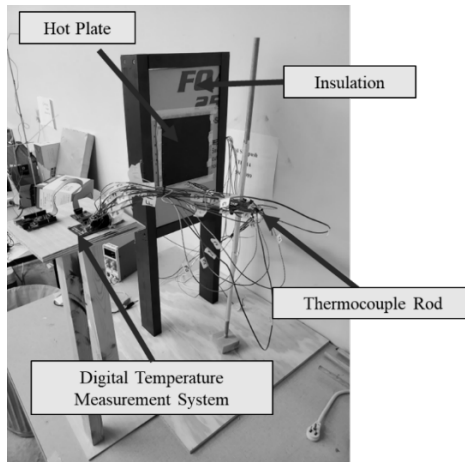


Figure 4. Final experimental set-up.

RESULTS AND DISCUSSION

TC Experiment

TCs were used to measure the air temperature at the specific distance intervals away from the plate. The temperature measurements started at the bottom of the plate and then moved up an inch (2.54 cm) at a time, with the temperatures recorded at each height until the top of the plate was reached. The average temperature values are summarized in Table 1. The highlighted cells represent air temperatures that are above the average ambient air temperature of 23.6°C. These cells represent the thermal boundary layer thickness moving up the plate. The thermal boundary is very thin at the bottom, then increases in thickness up the plate. The maximum thickness is approximately 1 in (2.54 cm). The boundary layer thickness is larger than was seen in the previous natural

convection experiment at CWU, which reported a boundary thickness of 0.5 in (1.27 cm) for a 6-in (15.24-cm)-square vertical plate [8]. Error introduced by conduction heat transfer through the TC rod is likely the biggest reason for this discrepancy.

Table 4. Thermocouple data at specific distances away from various heights of the plate

Height	1/8in	1/4in	1/2in	3/4in	1in	5/4in	3/2in	7/4in	2in	9/4in	5/2in	11/4in
8in	45.77	38.16	26.36	25.24	23.69	23.60	23.38	23.46	23.15	23.31	23.33	23.5
7in	45.38	35.38	26.07	25.15	23.66	23.62	23.26	23.48	23.15	23.23	23.21	23.4
6in	42.17	34.27	25.83	24.60	23.55	23.55	23.22	23.38	23.10	23.22	23.21	23.3
5in	43.42	33.83	25.66	24.44	23.70	23.51	23.34	23.55	23.15	23.23	23.31	23.4
4in	42.82	31.64	25.07	24.28	23.55	23.52	23.30	23.44	23.15	23.22	23.24	23.3
3in	40.77	30.84	25.08	24.05	23.47	23.51	23.25	23.39	23.13	23.20	23.20	23.4
2in	40.07	28.50	24.50	23.62	23.40	23.31	23.13	23.31	23.00	23.12	23.20	23.4
1in	38.12	27.61	23.96	23.40	23.30	23.22	23.12	23.25	22.98	23.10	23.12	23.4
0in	32.07	23.62	23.16	23.06	23.04	23.07	23.03	23.06	22.88	22.95	22.98	23.4

Schlieren Imaging

The Schlieren set-up was used to image the air flow next to the vertical heated plate, as shown in Figure 5. The flow of air appears laminar when compared with the types of flow shown in Figure 2. The darker lines in the image next to the plate show air with a lower density than the surrounding air. A line was added at the boundary layer, where the air appears undisturbed.

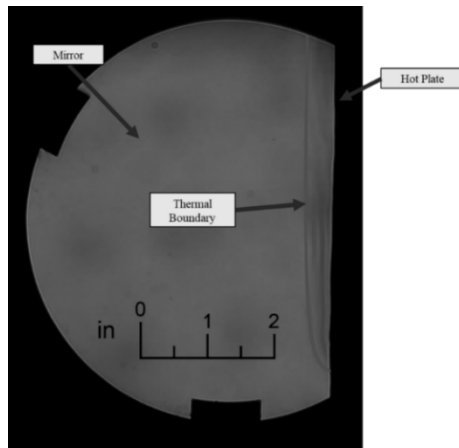


Figure 5. Schlieren image of the air next to the plate.

From the Schlieren images, the thermal boundary thickness along the height of the plate was approximated based on the reference height of the mirror. These values are shown in Table 2.

The thickness is 0 in at the bottom of the plate, 0.4 in (1.016 cm) halfway up the plate, and 0.5 in (1.27 cm) at the top of the plate. Although this is nearly half the thickness that was found experimentally, these values are consistent with those found in the CWU experiment.

Table 5. Schlieren imaging approximate thermal boundary thickness	
Height along plate (in/cm)	Thermal boundary layer thickness (in/cm)
8/20.32	0.5/1.2
4/10.16	0.4/1
0	0

Further analysis was performed using experimental temperatures and measurements to calculate various flow characteristics. These values are summarized in Table 3 and are compared with the values found in the CWU experiment. The Grashof number confirms that the flow is laminar, which is consistent with the Schlieren images. The Nusselt number and heat transfer coefficient differ from those observed in the CWU experiment, although they are consistent with laminar flow.

Table 6. Flow characteristic values for our experiment and the published CWU experiment		
Variable	Experimental value	CWU experimental values [9]
Heat transfer rate (W)	30.45	126.7
Grashof number	3.98×10^7	4.42×10^7
Nusselt number	72.13	43.89
Heat transfer coefficient ($\text{W}/\text{m}^2 \cdot \text{K}$)	15.34	8.9262

SOURCES OF ERROR

TC Experiment

During initial testing, the TC rod remained in constant contact with the hot plate, resulting in the conduction of heat through the rod. This resulted in high TC readings. Adjustments were made to reduce the contact time of the rod and the hot plate, but there could still have been some error caused by conduction. This could explain why the experimental boundary layer was thicker than the value obtained in the CWU experiment and what was seen using Schlieren imaging. The spacing between the TCs could also introduce error. The TCs were

placed 0.125 in (0.3175 cm) apart, causing the measured boundary layer thickness to have some uncertainty, because the distance away will be rounded down to the nearest 0.125 in (0.3175 cm). In addition, the spacing was not exact, because of slight movement after the sealant was applied. Another source of error was that the ambient air temperature was not constant around the experiment. This can be attributed to the movement of air in the testing room and was verified using a fluke thermometer (“62 MAX+ Handheld Infrared Laser Thermometer.” <https://www.fluke.com/en-us/product/temperature-measurement/ir-thermometers/fluke-62-max-plus>), which has an accuracy of $\pm 1^\circ\text{C}$ [13]. Without a precise ambient temperature, an average was used for comparison with the experimental values. In addition, the thermal camera revealed that the plate had nonuniform heating, as shown in Figure 6. This is most likely due to the heating pad and could have affected the shape of the boundary layer.

Schlieren Imaging

The Schlieren images were able to capture the thermal boundary layer and estimate its thickness; however, the actual thermal boundary layer is thought to be larger than what appears in the Schlieren images. This is partly due to perspective. The plate is closer to the camera than the mirror is, which affects how the proportions appear in the image.

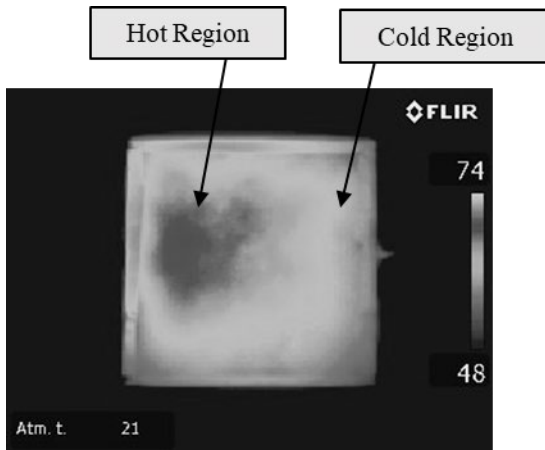


Figure 6. Thermal imaging of the plate showing that the heating was nonuniform.

Another factor is that, near the boundary layer, the temperature gradient is smaller. This means that the density variations are also smaller and therefore not noticeable in the Schlieren images. Both of these factors lead to the conclusion that the actual thermal boundary layer is larger than it appears in the images. Although it is difficult to speculate to what extent these factors affect the visible thickness, this conclusion is supported by the experimental data, which shows a larger boundary layer thickness than the Schlieren images.

The moving air in the room also could have reduced the clarity of the Schlieren images. Vents were blocked, but the airflow could not be completely controlled. This reduces the contrast between the thermal boundary layer and the surrounding air. Additionally, the temperature difference between the hot plate and ambient air was only 40–50°C. A larger temperature gradient would result in better Schlieren images, with more pronounced lines for the flow. This would also yield a thicker boundary layer, making it more visible.

CONCLUSION

A previous experiment conducted at CWU [8] was redesigned to determine the thickness of the thermal boundary layer on a vertical plate. Schlieren imaging was used to visualize the boundary layer and confirmed that the flow was laminar. From the images, the thermal boundary layer thickness appeared to be 0.5 in, nearly identical to the findings in the previous experiment [8]. Calculations were done to find the Grashof number, which validated that the flow was laminar. The TC experiment measured air temperatures at specific distances away from the plate, at varying heights up the plate. These measurements showed a parabolic, laminar boundary layer with a maximum thickness of approximately one inch.

The differences in the thickness can be attributed to sources of error in the experiment, primarily with the heating pad and conduction occurring through the TC rod. For future experiments, it is recommended that a larger mirror is used in Schlieren imaging, with a greater temperature gradient between the plate surface and surrounding air. This would allow the boundary layer to be seen more clearly. An improved future experiment would also include a more refined experimental set-up where the rod does not touch the hot plate, thus eliminating conduction. Smaller spacing between TCs would increase the resolution and provide a clearer image of the behavior of the thermal boundary layer. Further research is recommended regarding an analytical solution for the thermal boundary layer thickness. The analytical value could be

compared with the TC measurements and Schlieren images obtained in this experiment.

REFERENCES

- [1] Cengel, Y.A, and Ghajar, A.J. (2015) *Heat and Mass Transfer: Fundamentals & Applications* Fifth Edition, McGraw-Hill, New York.
- [2] Kabir E., Kumar C., and Goswami T. (2016) “Advances in natural convection heat transfer applications for food processing,” *Critical Reviews in Food Science and Nutrition* 56, pp. 1587–1600.
- [3] Naff R., Mungas G., Lutz A., and Anderson B. (2016) “Geothermal energy: An important renewable resource,” *Journal of Petroleum Technology* 68, pp. 76–84.
- [4] Bejan, A. (2013) *Convection Heat Transfer*, John Wiley & Sons, New York.
- [5] Ji J., Li Y., Yang L., and Zhang H. (2015) “A review of solar water heating systems for domestic and industrial applications,” *Renewable and Sustainable Energy Reviews* 41, pp. 308–323.
- [6] Jaluria, Y. (2005) *Design and Optimization of Heat Sinks*, John Wiley & Sons, New York.
- [7] Chen Y., Chen L., He Y., Liu H., and Wang Z. (2021) “A review on the natural ventilation technology in buildings,” *Applied Energy* 295, pp. 116-913.
- [8] Kaminski, W. (1998) “A series of heat transfer experiments for the mechanical engineering technology student: Lab 5. Free convection from a vertical surface,” Central Washington University, Ellensburg, WA.
- [9] Holman, J. (2010) *Heat Transfer*, McGraw-Hill, New York.
- [10] Settles, G. (2001) “Schlieren and Shadowgraph Techniques: Visualizing Phenomena in Transparent Media,” Springer Science & Business Media, Berlin.

[11] Gena, A. and Voelker, C. (2018) “Schlieren Imaging and Analysis,” Presented at 30th Forum Bauinformatik, Weimar, Germany, September 19-21, 2018.

[12] Krauss, R. (2010) “Schlieren Imaging Techniques for MEMS and Microfluidics,” Springer Science & Business Media, Berlin

APPENDIX A

Appendix A presents the materials and equipment used in the TC experiment and for Schlieren imaging.

MATERIALS AND EQUIPMENT

TC Experiment

- 19 TCs [1] and temperature sensor board DC-2420 (Fig. A-1)
- Black spray paint
- Heating pads each with an internal resistance of $2\ \Omega$ [2]
- 3D-printed TC rod
- 0.5-in diameter wooden dowel rod, 3 ft in length
- Eventek KPS3010D DC power supply [3] (Fig. A-2)
- 8×8 -in by 1-in thickness polyurethane foam insulation block
- 8×8 -in by 0.04-in thickness aluminum plate ($\epsilon=0.19$)
- NICEYRIG 90 Degree 15-mm rod clamp with adjustable screws [4]
- NASA Tech 2pcs Aerogel insulation 12×12 -in by 0.5-in thickness 2640F [5]
- Wooden frame
- Arduinos for 19-channel data logger set-up
- Stand for the Arduino set-up
- USB cable and laptop with 19-channel data logger program
- Fluke thermometer to measure surface temperature [6]
- Thermal imaging camera
- White marker
- Ruler
- Gasket sealant [7]
- Tape
- Assorted wood screws
- Aluminum foil

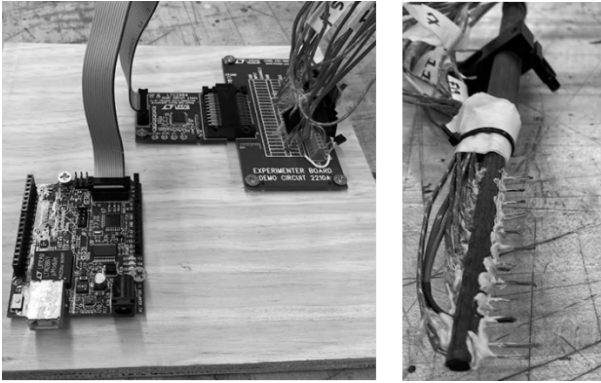


Figure A-1. Arduino 19-channel TC reader (right) and TC rod (left).



Figure A-2. Power source (left) used for the heated plate in the frame (right).

Schlieren Imaging (Fig. A-3)

- Concave mirror
- Razor blade and holder (Fig. A-4)
- Two 3-leg tripods
- Metal stand for Schlieren imaging
- Wooden shim
- Flashlight, flashlight holder, and pinhole cover (Fig. A-4)
- Camera with adjustable settings and lens

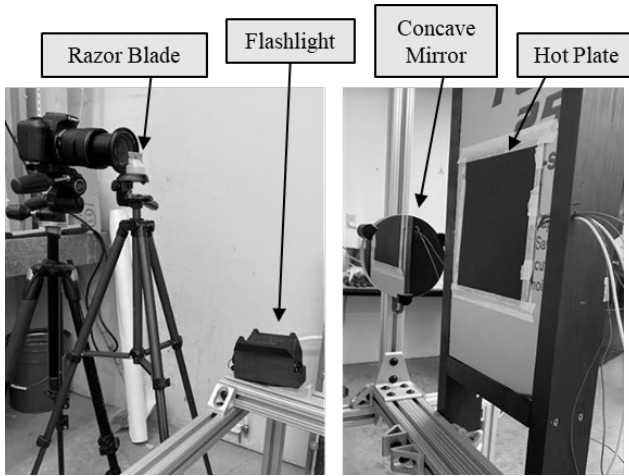


Figure A-3. Components of the Schlieren set-up.



Figure A-4. Schlieren components: razor blade (left) and flashlight (right).

APPENDIX B

Appendix B outlines the procedure used for the TC experiment and for Schlieren imaging.

PROCEDURE

The system to be analyzed consists of an 8×8 -in aluminum plate that has an 8×8 -in electrical resistance heat pad taped to one side. An $8 \times 8 \times 0.5$ -in Aerogel insulation pad is taped to the back of the resistance heat pad. The combined system is embedded in polyurethane insulation and suspended in the air using a wooden frame, as shown in Figure 5.

The system was analyzed to create a model for the thermal boundary layer using two methods: (a) Using TCs to measure the temperature of the air to see where it reaches ambient air temperature, and (b) using Schlieren imaging techniques.

TC Experiment

The following procedure was used to determine air temperatures at specific distances away from the hot plate:

- Spray-paint the aluminum plate black.
- Label 19 TCS to be used with the 19-channel data logger system.
- Attach the Arduinos for the TCs to a wooden board using screws.
- Record the location of each TC as it is placed in the experimental set-up.
- Note that some TCs may need to be threaded through the wooden frame when they are being placed.
- Use the 3D-printed PETg rod to hold 12 TCs.
- Each TC is inserted into the hole and then sealant and tape are used to hold the TCs in place. Let the sealant set for ~24 hours.
- Place 3 TCs on the back of the plate, one each at the bottom, middle, and top.
- Attach the heating pad to the back of the plate using tape around the edges.
- Tape the white Aerogel insulation to the back of the plate, covering the heating pad.
- Place 2 additional TCs on the back of the Aerogel insulation.
- Use machinery to carve out an $8 \times 8 \times 1$ -in depth area in the pink foam insulation.
- Place the plate, heating pad, and Aerogel insulation in the cut-out, then place the entire combination in the designated area of the wooden frame.
- Push in the insulation until the metal plate is flush with the insulation and the frame itself.
- Attach another TC to the back of the pink insulation.
- Attach a TC to the base of the wooden frame for ambient air temperature readings.
- Use a ruler and the white marker to label the plate in increments of 1 inch, starting at the bottom of the plate. Mark the increments in the middle of the plate and to the side for reference.

- Wrap the upper portion of the wooden dowel with aluminum foil as needed so that the clamp will fit on the rod. Place the clamp on the rod.
- Insert the wooden dowel into the designated location in the base of the frame.
- Use the clamp to hold the PETg TC rod perpendicular to the wooden dowel.
- Adjust the PETg TC rod so that the end is touching the face of the plate, with the TCs aligned horizontally in the air.
- Attach the USB from the Arduino board to a laptop, then lower the TC rod to test the ambient temperatures read by the TCs using the 19-channel data logger program.
- Once the temperatures are calibrated, turn on the power source to heat up the plate. Set the voltage to 8 V.
- Let the plate reach steady state, checking the temperature periodically with the Fluke thermometer. This should take approximately 40 min when the power source supplies 30 W.
- Throughout the experiment, be careful to not touch the plate because it reaches elevated temperatures that can cause injury.
- Use the computer program to log data throughout the experiment. It may be helpful to have one group member move the rod and the other run the computer program.
- Use the clamp to move the rod to the bottom of the plate (in the center) and ensure data is recorded on the computer program.
- Remove the rod from the plate, lower the rod, and monitor the TC temperatures until they appear to return to steady state.
- Once steady state is reached, move the rod up to the first marker on the plate (signifying a height of 1 inch) and record data.
- Repeat the same process with the rod after each reading to ensure temperatures decrease to ambient temperature prior to the next reading.
- Continue moving the rod up the plate in 1-in increments, recording measurements at each location.
- Repeat the experiment several times.
- While the plate is hot, take thermal images of the experimental set-up.
- Use the Fluke thermometer to take temperature measurements of the plate surface in 1-in increments up the plate.
- Turn off the power source and let the plate cool down.

Schlieren Imaging

The following procedure was followed to capture Schlieren images in this experiment:

- Heat up the vertical plate by connecting the heat pad to the power source.
- Mount the mirror on the metal stand.
- Place the hot plate directly in front of the mirror so that it is approximately in the center of the mirror and perpendicular to it.
- Place the flashlight in its holder with the pinhole and place them on the metal stand across from the mirror. Shine the light from the pinhole onto the mirror ensuring the entire mirror is illuminated.
- Place the razor blade in its holder onto a tripod. Position the razor blade exactly at the focus of the reflected light from the mirror. This may be easier with the lights off. Adjust the height of the razor blade so that it blocks approximately half of the light at the focal point.
- Place the camera on a tripod behind the razor blade. Position it so the remaining light (not obstructed by the razor blade) enters the lens. The angle of the camera may need to be adjusted to see the entire mirror illuminated. Adjust the focus of the camera to ensure the mirror is in focus.
- Ensure there is minimal airflow and allow the natural convection to develop on the hot plate for a few seconds.
- With the lights off, take a picture. Use a short timer on the camera so it does not shake during the picture. Note: the quality of the images can be increased by increasing the contrast in the images. This can be done by adjusting the camera settings and by blocking more light at the focal point with the razor blade.
- Adjust the height of the hot plate in front of the mirror to image both the top and bottom sections.

Product Sources

[1] “K-Type Thermocouple - ATB1 Bead Type Thermocouple-ATB1.” *TruTech Tools, Ltd.* Retrieved April 9, 2023, from https://www.trutechtools.com/ATB1?utm_source=google&utm_medium=surfaces&utm_campaign=shopping+feed&utm_content=free+google+shopping+clicks&gclid=Cj0KCQjwwf

[2] “4”×4” 100 × 100mm 12V 50W 70W w 3M Best Silicone Heater Heating Pads Flexible Mats.” *JSR Industries*. Retrieved March 11, 2023, from <https://www.jsr2.com/product/4-x-4-100-x-100mm-12v-50w-w-3m-best-silicone-heater-heating-pads-flexible-mats/>

[3] “DC Power Supply Adjustable (30V 10A), Eventek Variable Switching Regulated Digital Power Supply with Alligator Leads US Power Cord.” *Amazon.com*. Retrieved April 7, 2023, from https://www.amazon.com/Adjustable-Eventek-KPS3010D-Switching-Regulated/dp/B073TW8H2S?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&smid=A2ILE6JN92BB2Q&th=1

[4] “NICEYRIG 90 Degree 15mm Rod Clamp with ADjsutable Screws for Camera Support System Shoulder Rig Tripod System, Pack of 2.” *Amazon.com*. Retrieved February 9, 2023, from https://www.amazon.com/NICEYRIG-Degree-Adjustable-Support-Shoulder/dp/B06Y4CW8DF/ref=mp_s_a_1_1_sspa?crid=2U2S2OA3VDHL6&keywords=90+degree+rod+clamp&qid=1675987147&srefix=90+degree+rod+clamp%2Caps%2C141&sr=8-1-spons&pvc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUF

[5] “NASA Tech 2pcs Aerogel Insulation Padding Board (2 pcs) 12” x 12” x 0.5” 2640F (1448C) | Top Thermal Insulation Manufacturing Kaowool Ceramic Fiber Insulation.” *Amazon.com*. Retrieved on February 9, 2023, from https://www.amazon.com/Aerogel-Insulation-Padding-Thermal-Manufacturing/dp/B0BLK7BNPH/ref=asc_df_B0BLK7BNPH/?tag=hyprod-20&linkCode=df0&hvadid=642185390561&hvpos=&hvnetw=g&hvrnd=15223177071017970326&hvpon=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlo

[6] “62 MAX+ Handheld Infrared Laser Thermometer.” *FLUKE*. Retrieved April 7, 2023, from <https://www.fluke.com/en-us/product/temperature-measurement/ir-thermometers/fluke-62-max-plus>

[7] “Hi-temp red silicone gasket maker & sealant.” *jbweld.com*. Retrieved on April 7, 2023, from <https://www.jbweld.com/product/hi-temp-red-silicone>

Boiling and Cavitation Experiment for Engineering Undergraduate Labs

Savanah Higley and Ali Siahpush
Southern Utah University

ABSTRACT

The phase-change process is an important concept in fluid mechanics for mechanical engineering undergraduate students to understand. To better understand this process, experimental demonstrations are needed, but the required equipment is often too expensive to implement in an undergraduate laboratory setting. In this experiment, an inexpensive and practical apparatus was used to measure the vacuum pressure at which water boils at several temperatures above room temperature. The experimental data were then compared with published values and theoretical values calculated by using the Clausius-Clapeyron and Magnus equations to show the success of the experiment. This experiment proved to be an accurate way to predict the pressure at which water begins to boil, as the experimental values were very close to the published and theoretical values. Further uses of this experiment include a fluid mechanics experiment on cavitation or a thermodynamics saturation pressure measurement experiment.

INTRODUCTION

For engineering undergraduates, hands-on experiments and demonstrations are vital for understanding the curriculum. These experiments and demonstrations are important when teaching concepts in classes such as fluid mechanics and thermodynamics. Also, if possible and cost-effective, designing and building the apparatus can be a great learning opportunity. One of these concepts is the phase-change process of fluids, which helps students to understand cavitation and saturation pressure. Although there is equipment designed for laboratories to use when measuring this process, it can be expensive. One such apparatus is a chilled-mirror hygrometer, which ranges in cost from \$1,000 to \$30,000, making it difficult to implement in an undergraduate laboratory setting [1-2]. Throughout the technical literature, there are several experiments where expensive equipment was redesigned to measure the phase-change process [3-4]; however, it is not always possible or practical to replicate this equipment in an undergraduate classroom, because the equipment often requires custom-made parts from manufacturing companies.

The primary purpose of this study was to design and build a cost-effective and practical experiment to measure the vacuum pressure at which water boils at several temperatures above room temperature; the purpose of this experiment is to understand how and when water changes to vapor. The measured pressures were then compared with theoretical pressures found through the Clausius-Clapeyron [5] and Magnus [6] equations and published values to determine the accuracy of the experimental set-up.

THEORY

To understand the thermodynamic behavior of water, it is important to understand the concept of vapor pressure. Vapor pressure is defined as the point where liquid molecules of fluid begin to change to vapor [7]. It is a property dependent on the thermal and physical properties of a fluid and the operating temperature. When the vapor pressure of a fluid reaches the surrounding atmospheric pressure, the fluid will begin to boil. Vapor pressure P_v is measured in gauge, and it can be converted to absolute pressure as [8]

$$P_{abs} = P_{gauge} + P_{atm} \quad (1)$$

where P_{abs} is the absolute pressure (kPa), P_{gauge} is the gauge pressure (kPa), and P_{atm} is the atmospheric pressure at the elevation of interest (kPa).

There are several valid relations to determine and predict the pressure at which a fluid will begin to boil at a given temperature. Two of these relations, frequently used, are the Clausius-Clapeyron equation and the Magnus equation. The Clausius-Clapeyron equation is given by [5]

$$P_{theoretical} = P_0 e^{-\frac{\Delta H}{R} - \left(\frac{1}{T_0} - \frac{1}{T_B}\right)} \quad (2)$$

where $P_{theoretical}$ is the absolute theoretical pressure (kPa), P_0 is the pressure at the elevation of interest (kPa), ΔH is the heat of evaporation (kJ/kg), R is the ideal gas constant, T_0 is the boiling temperature at the elevation of interest (K), and T_B is the boiling temperature at the pressure of interest (K). The Magnus equation is given by [6]

$$P_{theoretical} = 0.61094 e^{\left(\frac{17.625T}{T+243.03}\right)} \quad (3)$$

where T is the temperature at the elevation of interest ($^{\circ}\text{C}$). This process may serve as a fluid mechanics lab in understanding cavitation. Cavitation occurs when vapor (bubbles) form because of the suction pressure at a pump inlet being too low. This phenomenon can lower the performance of a pump, and if allowed to continue, can destroy the pump. This process also serves as a thermodynamics lab to measure phase change at low pressures tabulated in thermodynamics books as saturation pressure and temperatures [9].

MATERIALS

The following materials were used to complete the experiment.

- Water
- Mason jar
- Hand pump apparatus [10] (Fig. 1)
- Cuisinart Countertop Burner [11] (Fig. 2)
- Pot (Fig. 2)
- Glass mercury thermometer

Figure 1 shows the equipment breakdown of the hand pump apparatus, which includes a Mityvac hand pump, a vacuum pressure gauge, and tubing connecting the pump to the mason jar lid.

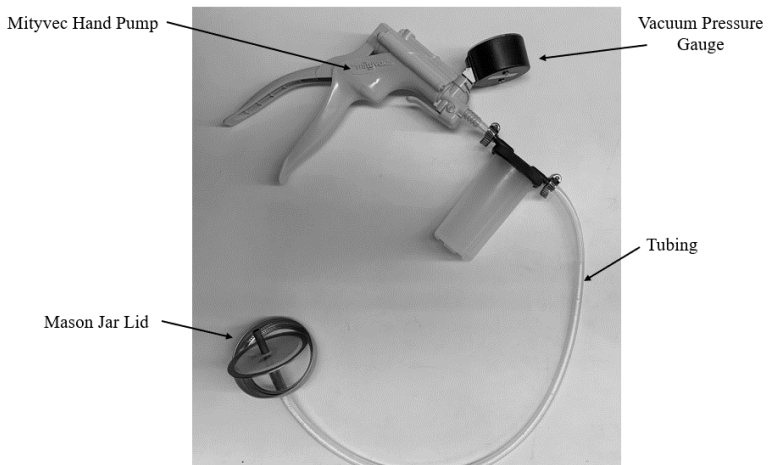


Figure 1. Hand pump apparatus.

Figure 2 shows the Cuisinart Countertop Burner and the pot used to heat the water for the experiment.



Figure 2. Cuisinart Countertop Burner and pot used to heat water.

PROCEDURE

The following steps were followed to complete the experiment.

- Place water in the pot and heat using the Cuisinart Countertop Burner until the water is boiling. Safety glasses and gloves should be worn when handling hot water.
- Transfer water from the pot to the mason jar and fill the mason jar approximately halfway full.
- Measure the temperature of the water with the thermometer. Slowly add cold water until the water is at approximately 60°C. Record the temperature.
- Attach the hand pump apparatus to the mason jar.
- Use the hand pump to lower the pressure. Make sure the tubing does not collapse and that the pressure on the gauge is decreasing.
- Continue pumping until the water begins to boil.
- Record the pressure on the vacuum pressure gauge.
- Carefully dispose of the water.
- Repeat steps 3-9 for temperatures approximately at 65°C, 70°C, 75°C, 80°C, and 85°C.

RESULTS AND DISCUSSION

In this experiment, the gauge pressure was recorded when the water in the mason jar began boiling at various temperatures. Figure 3 shows an image of the water boiling, at the recorded vacuum pressure.



Figure 3. Water boiling in the mason jar.

Table 1 shows the experimental, Clausius-Clapeyron theoretical, Magnus theoretical, and published values for absolute pressure for

temperatures ranging from 60 to 85°C. (The sample calculations are presented in the Appendix.) The Clausius-Clapeyron theoretical values were calculated using Eq. (1) and Eq. (2). The Magnus theoretical values were calculated using Eq. (1) and Eq. (3). Equation (1) for the theoretical values were calculated using the atmospheric pressure of Cedar City, Utah (approximately 83.84 kPa.). It should be noted that the published values are for the sea level and, as expected, the boiling temperatures are higher than the boiling temperatures at Cedar City elevation.

Table 1. The experimental, theoretical, and published values of absolute pressure for various temperatures					
T (°C)	Experimental	Clausius-Clapeyron	Magnus	Published Values	
	P (kPa)	P (kPa)	P (kPa)	T (°C)	P (kPa)
60.5	21.06	20.81	20.49	60	19.95
66.0	26.15	26.39	26.35	65	25.04
70.5	31.24	31.87	32.14	70	31.20
77.0	40.74	41.51	42.42	75	38.60
80.0	45.83	46.74	48.04	80	47.42
85.0	54.99	56.71	58.80	85	57.89

Figure 4 shows a comparison of the absolute pressure and temperature for the experimental, Clausius-Clapeyron theoretical values, Magnus theoretical values, and published values.

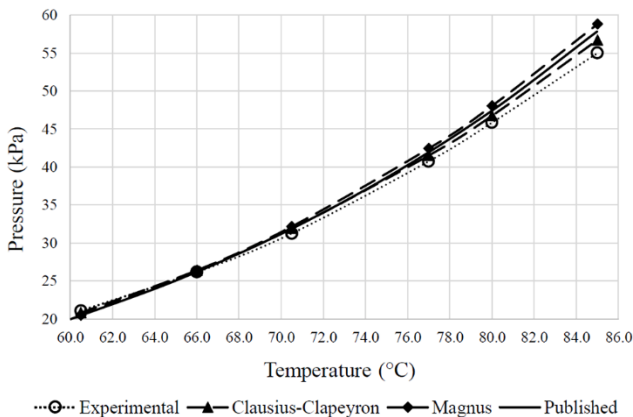


Figure 4. The experimental, theoretical, and published values for absolute pressure versus temperature.

To determine the accuracy of this experiment, the theoretical data calculated from the Clausius-Clapeyron and Magnus equations were compared with the experimental data with percent error. The corresponding percent error values for each temperature and the average percent error are shown in Table 2. When compared with the Clausius-Clapeyron theoretical values, the error ranged from 0.91% to 3.03%, with an average error of 1.82%. When compared with the Magnus theoretical values, the error ranged from 0.75% to 6.47%, with an average error of 3.56%. The percent error shows the data collected from the experiment is fairly accurate, because the average error is under 5% for both the Clausius-Clapeyron and Magnus equations. The experimental results were expected to be lower than the theoretical values because the jar was continuously losing heat as the experiment was performed.

Temperature (°C)	% Error	
	Clausius-Clapeyron	Magnus
60.5	1.22	2.76
66.0	0.91	0.75
70.5	1.99	2.81
77.0	1.85	3.97
80.0	1.94	4.59
85.0	3.03	6.47
Average % Error	1.82	3.56

SOURCES OF ERROR

Although the results of the experiment were fairly accurate, several sources of error may have led to discrepancies in the data. The first possible source of error is experimental error. The water in the jar was not held at a constant temperature throughout the experiment, meaning heat was lost when decreasing the pressure in the jar. This resulted in inaccurate temperature measurements of when the water began to boil. When pulling vacuum with the hand pump, the vacuum pressure gauge would move very slowly or show no change at all. This may have been because of air leaks in the tubing or at the connection points. When the temperature of water/vapor was above 70°C, the tubing would sometimes collapse while pulling vacuum using the hand pump, which also may have led to inaccuracies in the vacuum pressure measurements.

Along with experimental error, there is error due to the inaccuracies of the equipment. The vacuum pressure gauge used in the hand-pump apparatus had an error rating of 0.1% to 0.25% of reading, which could

explain some of the small discrepancies in the data [12]. There is also possible human error in the experiment, because the temperature and the vacuum pressure values were measured with the human eye. Lack of precision with both the thermometer and the vacuum pressure gauge would also add to the error.

To reduce these sources of error, a more accurate way to measure the vacuum pressure should be implemented, such as a digital pressure gauge. This would reduce the human error present in the experiment, yielding more accurate results. A more effective way to seal the connection points of the tubing should also be implemented, such as using seals or clamps. Doing so would reduce the possibility of air leaks and would ensure a more accurate vacuum pressure measurement.

CONCLUSION AND RECOMMENDATIONS

The purpose of this paper was to design and build a cost-effective experiment to measure the vacuum pressure at which water begins to boil at several temperatures above room temperature to better understand the phase-change process of water. The temperature and vacuum pressure values measured in this experiment were compared with theoretical values calculated using the Clausius-Clapeyron [5] and Magnus [6] equations and with published values [9]. The average error in this experiment was 3.56%. Despite the slight error, the experiment was deemed to be a success because the experimental values were very close to the theoretical and published values. Further uses of this experiment include a fluid mechanics lab on cavitation or a thermodynamics lab on saturation pressure.

To reduce the error present in the experiment, it is recommended to use a more accurate pressure gauge, such as a digital gauge, when taking measurements. It is also recommended to use seals or clamps on the pump tubing to reduce possible air leaks at the connection points.

REFERENCES

[1] P.R. Weiderhold, "Chilled Mirror Hygrometers," in *Water Vapor Measurement*, CRC Press, 1997.

[2] "Chilled mirror hygrometers," *Instrumart*. [Online]. Available: https://www.instrumart.com/productsets/285/chilled-mirror-hygrometers?gclid=CjwKCAiA76-dBhByEiwAA0_s9ao-1tLuHTjFTIdGvxNZsoZpE3ExZP8QMuzI-ZYf0CZO4yW528PFuxoCNk8QAvD_BwE. [Accessed: 28-Dec-2022].

- [3] C. Wenqian, A.J. Haslam, A. Macey, U.V. Shah, and C. Brechtelsbauer, “Measuring Vapour Pressure with An Isoteniscope - A Hands-On Introduction to Thermodynamic Concepts,” *Journal of Chemical Education* 93 (5), pp. 920-926, 2016.
- [4] N. Fukata and C. Gramada, “Vapor Pressure Measurement of Supercooled Water,” *Journal of the Atmospheric Sciences* 60 (15), pp. 1871-1875, 2003.
- [5] E. Shpilrain, “Clapeyron-Clausius equation,” In *Thermopedia: Guide to Thermodynamics, Heat & Mass Transfer, and Fluids Engineering*. DOI: 10.1615/AtoZ.c.clapeyron-clausius_equation. 2011.
- [6] J. Huang, “A simple accurate formula for calculating saturation vapor pressure of water and Ice,” *Journal of Applied Meteorology and Climatology* 57 (6), pp. 1265–1272, 2018.
- [7] International Association for the Properties of Water and Steam, “What is the effect of pressure on the boiling of water? Why does water boil at a lower temperature at high altitudes?” Retrieved November 21, 2022, from <http://www.iapws.org/faq1/boil.html>.
- [8] R.L. Mott and J.A. Untener, *Applied Fluid Mechanics*. Harlow, Essex, England: Pearson Education Limited, 2016.
- [9] Y.A. Çengel and M.A. Boles, *Thermodynamics: An engineering approach, Eighth Edition*. New York: McGraw-Hill Education, 2015.
- [10] “Mityvac MV8000 Professional single person manual brake and Clutch Bleeding Tune-up Kit,” Accessed March 1, 2023, at <https://www.amazon.com/mv8000-automotive-tune-up-brake-bleeding/dp/b00265m9ss>.
- [11] “Cuisinart CB-30P1 Cast-iron single burner, Stainless Steel.” Accessed March 1, 2023, at <https://www.amazon.com/Cuisinart-CB-30-Cast-Iron-Single-Stainless/dp/B01IA3H8QM>.
- [12] Brannan Co., “Pressure gauges—accuracy explained,” Accessed February 10, 2021, at https://www.brannan.co.uk/knowledge_base/pressure-gauges-accuracy-explained/.

APPENDIX

In this Appendix, the sample calculations for the experimental and theoretical values of pressure for the measured temperatures are presented. The experimental pressure values were determined by taking the average measured vacuum gauge pressure values and calculating the absolute pressure. The absolute pressure was then converted from inHg to psi to kPa (Fig. A1). The theoretical values were calculated using the measured temperatures for the Clausius-Clapeyron and Magnus equations (Fig. A2).

Experimental:

1. convert gauge pressure to absolute pressure

$$P_{abs} = P_{gauge} + P_{atm}$$

FOR 60.5 °C → $P_{gauge} = -16.5$ inHg
 FOR Cedar City, Utah → $P_{atm} = 24.706$ inHg

$$P_{abs} = -16.5 \text{ inHg} + 24.71 \text{ inHg}$$

$$P_{abs} = 6.21 \text{ inHg}$$

2. convert inHg to psi

$$P_{abs} = \gamma_m (\text{sg. Hg}) P_{abs} (\text{inHg})$$

$$\gamma_m = 62.4 \frac{\text{lb}}{\text{ft}^3}, \text{sg. Hg} = 13.63$$

$$P_{abs} = 62.4 \frac{\text{lb}}{\text{ft}^3} \left(\frac{1 \text{ ft}}{12 \text{ in}} \right)^3 (13.63) (6.21 \text{ inHg})$$

$$P_{abs} = 3.054 \text{ psi}$$

3. convert psi to kPa

$$P_{abs} = \frac{3.054 \text{ psi} | 6.89 \text{ kPa}}{1 \text{ psi}}$$

$$P_{abs} = 21.06 \text{ kPa}$$

* FOLLOW THIS PROCESS FOR T = 66.0, 70.0, 70.5, 77.0, 80.0, 85.0 °C *

Figure A1. Sample calculations for the experimental values.

Theoretical - Clausius-Clapeyron:

$$P_{\text{theoretical}} = P_0 e^{\frac{-\Delta H}{R} \left(\frac{1}{T_0} - \frac{1}{T_B} \right)}$$

For Cedar City, Utah $\rightarrow P_0 = 83.84 \text{ kPa}$, $T_0 = 95.56^\circ\text{C}$

$$\Delta H = 40650 \frac{\text{J}}{\text{mol}}$$

$$R = 8.31145 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

$T_B \rightarrow$ measured temperature water boiled at (K)

1. convert T_0 & T_B from $^\circ\text{C}$ to K

$$T_0 = 95.56^\circ\text{C} + 273.15 \text{ K}$$

$$T_0 = 368.71 \text{ K}$$

For $T_B = 60.5^\circ\text{C}$

$$T_B = 60.5^\circ\text{C} + 273.15 \text{ K}$$

$$T_B = 333.65 \text{ K}$$

2. calculate $P_{\text{theoretical}}$

$$P_{\text{theoretical}} = (83.84 \text{ kPa}) e^{\left(\frac{-40650 \frac{\text{J}}{\text{mol}}}{8.31145 \frac{\text{J}}{\text{mol}\cdot\text{K}}} \right) \left(\frac{1}{368.71 \text{ K}} - \frac{1}{333.65 \text{ K}} \right)}$$

$$P_{\text{theoretical}} = 20.81 \text{ kPa}$$

* FOLLOW THIS PROCESS FOR $T = 66.0, 70.0, 70.5, 77.0, 80.0, 85.0^\circ\text{C}$ *

Theoretical - Magnus:

$$P_{\text{theoretical}} = 0.61094 e^{\left(\frac{17.625 T}{T + 243.05} \right)}$$

$T \rightarrow$ measured temperature water boiled at ($^\circ\text{C}$)

For $T = 60.5^\circ\text{C}$

$$P_{\text{theoretical}} = 0.61094 e^{\left(\frac{17.625 (60.5^\circ\text{C})}{60.5^\circ\text{C} + 243.05} \right)}$$

$$P_{\text{theoretical}} = 20.49 \text{ kPa}$$

* FOLLOW THIS PROCESS FOR $T = 66.0, 70.0, 70.5, 77.0, 80.0, 85.0^\circ\text{C}$ *

Figure A2. Sample calculations for the Clausius-Clapeyron and Magnus theoretical values.

Effective Thermal Conductivity of Porous Copper Foam Saturated with Eicosane Phase-Change Material

MaryJo Taylor and Ali Siahpush
Southern Utah University

ABSTRACT

This experimental study evaluated the effective thermal conductivity of a solid/liquid phase-change thermal energy storage system that includes porous copper foam. The phase-change material (PCM) and metal foam were contained in a vertically oriented test cylinder that is cooled at its outside boundary, resulting in radially inward freezing. As the PCM freezes, the solid/liquid interface moves inward from the surface of the test cylinder, and a thermal resistance layer is built up, resulting in a reduced heat transfer rate between the system to be cooled and the PCM. The porous copper reduced the insulating effect of this thermal resistance layer. In the freezing case study, a one-dimensional mathematical model was developed, which considered heat conduction as the only mode of heat transfer. Experimental results were used in the heat conduction and heat balance integral methods to evaluate the effective thermal conductivity. Six analytical models were used to predict the effective thermal conductivity. The results of this study evaluated the effectiveness of the metal foam as a heat transfer enhancement device.

Nomenclature	
C_p	specific heat (J/kg·K)
d	metal matrix characteristic pore diameter (m)
Fo	Fourier number, $Fo = at/r_w^2$
h_{fus}	latent heat of fusion (J/kg)
k	thermal conductivity (W/m·K)
k_{eff-s}	effective thermal conductivity of copper porous foam (W/m·K)
r	radius (m)
St_s	solid Stefan number $St_s = C_{ps}(T_{fus} - T_w)/h_{fus}$
t	time (s)
$T(r)$	temperature (°C)
Δt	time step (s)
ΔT	instantaneous temperature difference between inlet and outlet of CTB fluid (°C)
Q_1	incremental heat transfer to the system from cooling water unit
Q_2	total heat transfer to each component from the cooling water v
Q_{f-s}	sensible heat released by subcooling the frozen solid below the fusion temperature unit
Q_{fus}	latent heat of fusion unit
Q_{sen}	sensible heat released from liquid remaining unfrozen
α_{eff-s}	effective solid thermal diffusivity (m ² /s)
β_r	dimensionless radius of fusion
ρ	density (kg/m ³)
τ	dimensionless time
ϕ	porosity
ψ	heat balance integral
eff	effective
f	final
fus	fusion
I	initial
por	porous material
o	initial condition
s	solid phase
sen	sensible heat
w	wall

INTRODUCTION

The low thermal conductivity of frozen phase-change material (PCM) and the growing thickness of a PCM requires a larger temperature difference to keep the heat flux at an effective value; the larger this temperature difference, the greater the refrigerator power requirement. The problem of “self-insulation” may be remedied by exploring a method of increasing the effective thermal conductivity of the phase-change material. A metal matrix is particularly suited to this application. The porous metal matrix inserted into the PCM enhances heat transfer during phase-change processes and will result in a higher effective thermal conductivity. This heat transfer situation can be termed solid-liquid phase-change heat transfer in saturated porous media.

The use of porous materials to enhance heat transfer has been investigated by numerous researchers. Viskanta et al. [1] and Weaver [2] have investigated freezing of water in porous media experimentally and analytically for horizontal and vertical cylindrical capsules. Quantitative results of the temperature distribution and solid-liquid interface shape were obtained for inward freezing with different sizes and types of spherical beads used as the porous media. A mathematical model, based on a one-dimensional analysis, which considered heat conduction as the only mode of heat transfer in both liquid and solid regions, was developed, and the regions in which natural convection becomes significant were investigated.

Qian et al. [3] proposed a two-dimensional Lattice-Boltzmann model for analyzing the heat conduction process in the porous media. The effective thermal conductivities of several porous materials were calculated using this model. The calculated results were found to be in excellent agreement with the experimental data of the existing references. Wang and Pan [4] developed a random generation-growth method to reproduce the microstructures of open-cell foam materials via computer modeling. The effective thermal conductivities of open-cell foam materials were numerically calculated and the predictions were compared with the existing experimental data. They showed that the numerical predictions agree well with the experimental data.

Mendes et al. [5] proposed an analytical solution for the determination of effective thermal conductivity (ETC) of open-cell foam-like structures for any working fluid based on the predicted ETC under vacuum. Their method provided estimations for the ETC of open-cell foam-like structures and can also be used for the indirect measurement of the ETC in the presence of hazardous working fluids. Xiao et al. [6] studied copper and nickel foams with various porosities and pore sizes impregnated with pure paraffin with vacuum assistance.

A steady-state test system was constructed to measure the effective thermal conductivities of the composite PCMs. The thermal conductivities were also theoretically calculated based on the correlations and models from the literature. Their results showed that the thermal conductivities measured with the steady-state method had good agreement with the theoretical predictions, and the thermal conductivities of the composite PCMs were dramatically enhanced.

Li et al. [7] elaborated paraffin/expanded graphite composite (EG) powder with various weight fractions by high-pressure compression. The saturation sorption capacity of EG under compression was experimentally determined. They showed that the thermal conductivity of the paraffin/EG composite is enhanced by 41 times in maximum as compared with pure paraffin. Their numerical results agreed well with the experimental data that validated the precision and reliability of the proposed model.

Wang et al. [8] constructed a numerical platform to test the thermo-physical properties of pure paraffin and copper foam. Their results showed that copper foam can effectively improve the internal heat transfer uniformity of paraffin, reduce the heat storage time of paraffin wax by 40%, and improve the relationship between the total phase transition time and the heating boundary temperature in the copper/paraffin composite PCMs. Moenini Sedegh and Khodadadi [9] investigated the effective thermal conductivity of composites of graphite foam infiltrated with phase change materials numerically and experimentally. Their results indicated a noticeable improvement in the effective thermal conductivity of composites compared with the PCM. Their numerical and experimental results were consistent with reported experimental results on graphite foam.

Asakuma and Yamamoto [10] conducted thermal conductivity investigations by homogenization. They investigated the factors that determine the effective thermal conductivity of porous structures and composites, such as the volume ratio of the continuous and dispersed phases, conductivity ratio, Biot number, and particle packing model. Gruescu et al. [11] were concerned with the determination of the effective thermal conductivity of porous rocks or rock-like composites composed of multiple solid constituents in partially saturated conditions. In their work, the predictive capacities of the two-step homogenization method were evaluated by comparison with experimental results obtained for argillite.

Aurangzeb [12] modeled and measured the density-related properties of igneous (dunite and gabbro) and sedimentary (limestone) rocks at room temperature and normal pressure, using ASTM Standards. The author also proposed an empirical model to evaluate effective

thermal conductivity. The results of this relation agreed with the results obtained from the existing models. Imran [13] performed an experimental hydrogeological analysis of thermal convection in saturated porous media using a noninvasive and contactless temperature measuring technique known as infrared thermography. Two-dimensional laboratory experimental results were conducted in three porous media under stable miscible displacement of injected water.

In this research, a detailed experimental study has been performed to evaluate the effective thermal conductivity of a solid/liquid phase-change thermal energy storage system that includes porous copper foam. The PCM and metal foam were contained in a vertically oriented test cylinder that is cooled at its outside boundary, resulting in radially inward freezing. As the PCM freezes, the solid/liquid interface moves inward from the surface of the test cylinder, and a thermal resistance layer is built up, resulting in a reduced heat transfer rate between the system to be cooled and the PCM. In the freezing case study, a one-dimensional mathematical model was developed, which considered heat conduction as the only mode of heat transfer. The effective thermal conductivity of the porous copper saturated with solid eicosane was predicted using several models and compared with the measured effective thermal conductivity.

TEST VESSEL SYSTEM

The experiments were performed at Southern Utah University in a cylindrical copper test vessel. To provide a controlled constant wall temperature thermal boundary condition, a pair of copper tubes were wrapped and soldered around the outside of the copper test vessel with two tube inlets, each at opposite ends of the test vessel. In this manner, the double-wrapped tubing acted as a counterflow heat exchanger to provide a uniform wall temperature boundary condition around the outer periphery of the test vessel. The test vessel with the copper tubes mounted on the tank is shown in Figure 1 [14]. The test vessel was fabricated from a large-diameter copper tube with an inside diameter of 15.55 cm, an outside diameter of 16.19 cm, and a height of 30.48 cm. The thick-walled cylinder was selected to provide a uniform wall temperature experimental boundary condition. A constant temperature bath (CTB) was selected to supply cooling/heating fluid to the copper heat exchange tubes. Demineralized water was used as the heat transfer fluid. The CTB served as the heat sink, providing cold water to the test vessel system. The properties of materials used in this experiment are presented in Table 1.

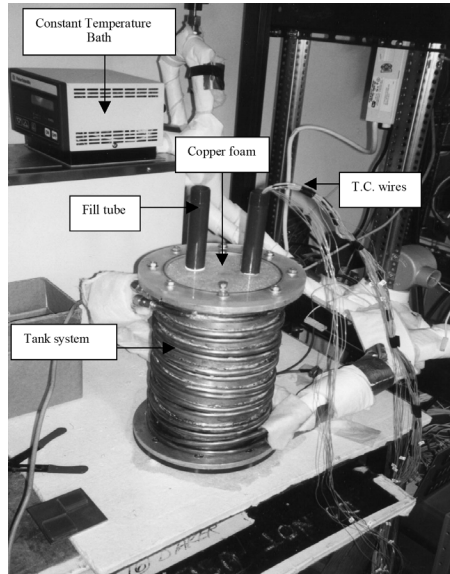


Figure 1. Tank system with copper foam.

Table 1. Material properties at room temperature [15]			
Material	Thermal Conductivity (W/m.K)	Specific Heat (J/kg.K)	Density (kg/m³)
Copper	401	385	8933
Aluminum	177	875	2770
Insulation	0.038	835	32
Acrylic	0.159	1450	1190

For these experiments, 99% pure eicosane ($C_{20}H_{42}$) was chosen as the PCM. Eicosane is desirable because its fusion temperature is just slightly higher than the ambient temperature ($36.5^{\circ}C$), which is convenient for phase-change experimentation. Low-temperature heating can be used to melt the PCM, and ambient-temperature cooling can be used to refreeze it. In addition, the proximity of the melting point to ambient temperature results in reduced heat losses to the ambient environment, assisting calorimetric measurements. The thermal properties of eicosane are presented in Table 2.

Table 2. Thermal properties of solid eicosane [16]	
Property	Value
Solid thermal conductivity k_s (w/m-C)	0.423
Density ρ_s (kg/m ³)	840
Latent heat of fusion Δh_{fus} (kJ/kg)	239.94
Specific heat C_{ps} (kJ/kg-C)	1.92

FREEZING WITH EICOSANE PCM WITH POROUS METAL FOAM

For testing the test vessel system, cylindrical disks of copper metal foam with a 95% porosity were machined to fit securely in the tank. Eighty-one thermocouples were positioned in the copper foam to monitor the progression of the freeze front of the liquid eicosane.

Four freezing tests were performed to provide redundancy and to fully understand the behavior of the copper porous foam saturated with molten eicosane, initially at 50°C, as it was solidified to a temperature of 10°C.

Inspection of the thermocouples indicated that after ~20 minutes, the effect of natural convection disappeared and the entire tank reached the fusion temperature of 36.5°C. Consequently, the heat transfer mechanism became pure conduction. The entire system, including the eicosane and the water flow, reached thermal equilibrium at 10°C after about 150 minutes. In the freezing process, the following assumptions were made to simplify the analysis: 1) no convection heat transfer in the liquid; 2) one-dimensional heat transfer in the radial (r) direction; 3) physical properties are independent of temperature but different for each phase; 4) overall volume change due to phase change is assumed to be negligible; 5) the solid-liquid interface is clearly defined; and 6) the porous media is isotropic and homogeneous, with uniform porosity.

In this analysis, the effective or average thermophysical properties were used; these are based on the fraction of each constituent to take into account the porous properties [16]

$$\begin{aligned}
 (\rho C_p)_{\text{eff-s}} &= \varphi(\rho C_p)_s + (1 - \varphi)(\rho C_p)_{\text{por}} \\
 \alpha_{\text{eff-s}} &= \frac{k_{\text{eff-s}}}{(\rho C_p)_{\text{eff-s}}} \\
 \rho_{\text{eff-s}} &= \varphi \rho_s + (1 - \varphi) \rho_{\text{por}}
 \end{aligned}
 \tag{1}$$

where subscripts eff-s, s, and por refer to the properties of aggregated solid-porous, solid, and porous copper, respectively. Also, the porosity of the copper foam (φ) is assumed to be 95%.

Conduction Model

During the freezing process, taking into account the six assumptions, conduction is the only mode of heat transfer in a radial direction after a short period of time. The heat conduction equation for solid is defined as [17]

$$\frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial T}{\partial r} \right)_{ps} = \left(\frac{1}{\alpha} \frac{\partial T}{\partial t} \right)_{ps} \quad (2)$$

where subscript *ps* refers to the solid influenced by the porous medium. The initial (*i*) and boundary conditions for freezing are defined as

$$\begin{aligned} T_l &= T_i \quad \text{for} \quad t \leq 0 \\ T_s &= T_w \quad \text{at} \quad r = r_w \\ T_s &= T_l = T_{fus} \quad \text{at} \quad r = r_{fus} \\ \frac{\partial T}{\partial r} &= 0 \quad \text{at} \quad r = 0 \end{aligned} \quad (3)$$

where r_{fus} represents the radial location of the radius of fusion (m). Considering no convection heat transfer in liquid, the energy balance at the interface yields [17]

$$\rho_{\text{eff-s}} h_{\text{fus}} \left(\frac{\partial r}{\partial t} \right)_{\text{fus}} - k_{\text{eff-s}} \left(\frac{\partial T}{\partial r} \right)_{ps} = 0 \quad (4)$$

where h_{fus} is the latent heat of fusion (unit), $k_{\text{eff-s}}$ is the effective thermal conductivity of solid eicosane and the copper foam (W/m·K). For the steady-state and one-dimensional heat transfer conduction, from Eq. (2), the heat conduction equation in the solid region may be integrated to yield the temperature distribution, $T(r)$ as

$$T(r) = T_w + \frac{(T_{fus} - T_w)}{\ln(r_{fus}/r_w)} \ln(r/r_w) \quad (5)$$

Substituting $T(r)$ from Eq. (5) into Eq. (4) and solving the resulting differential equation, the location of the phase-change interface, r_{fus} , can be evaluated [18] as

$$\begin{aligned} 2 \left(\frac{r_{fus}}{r_w} \right)^2 \ln \left(\frac{r_{fus}}{r_w} \right) - \left(\frac{r_{fus}}{r_w} \right)^2 + 1 &= 4 \left(\frac{\alpha_{\text{eff-s}} t}{r_w^2} \right) \left(\frac{c_{ps} (T_{fus} - T_w)}{h_{\text{fus}}} \right) \\ &= 4 \text{Fo}_{ps} \text{St}_{ps} \end{aligned} \quad (6)$$

where Fo_{ps} is the effective Fourier number (dimensionless time) and St_{ps} is the effective Stefan number of the solid.

Equation (6) may be solved iteratively for the phase-change interface location, r_{fus} , at any time. A comparison between r_{fus} evaluated

experimentally and r_{fus} prediction from the conduction model, Eq. (6), is shown in Figure 2. As expected, because the pure-conduction model ignores the initial effects of natural convection, the experimental values are higher than the pure-conduction predictions for a small period of time. Natural convection in the molten region (50°C) tends to modestly delay the inward progression of the freezing front. This convection effect disappears after 20 minutes of elapsed test time, at which point the temperature of the liquid eicosane achieves the fusion temperature (36.5°C).

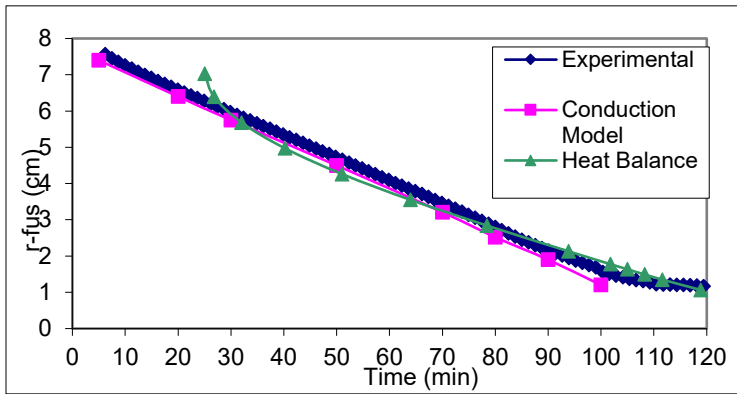


Figure 2. Analytical solution for inward freezing, porous metal foam case.

Integration of Eq. (2), the energy equation, yields the heat balance integral equation [19, 20] as

$$\alpha_{\text{eff-s}} \left(r \frac{\partial T}{\partial r} - r_w \frac{\partial T}{\partial r} \right) = \frac{d\psi_s}{dt} - r_{\text{fus}} T_{\text{fus}} \frac{dr}{dt} \tag{7}$$

where ψ_s is the heat balance integral, given by [21]

$$\psi_s = \int_{T_w}^{T_{\text{fus}}} r T dT \tag{8}$$

The solution of Eq. (8) is obtained by assuming a logarithmic relation for the temperature profile in the solid [17, 22] as

$$T = T_w - (T_w - T_{\text{fus}}) \frac{\ln\left(\frac{r}{r_w}\right)}{\ln\left(\frac{r_{\text{fus}}}{r_w}\right)} \tag{9}$$

Substituting Eq. (9) into Eq. (7) and solving for the dimensionless time (τ) as a function of the dimensionless radius of fusion (β_r) yields [21]

$$\tau = \frac{St_{ps}}{4} [\beta_r^2 - 1 - 2\ln\beta_r - (\ln\beta_r)^2 - \dots - \frac{2^n (\ln\beta_r)^2}{n!}] + \frac{\beta_r^2}{2} \ln\beta_r - \frac{\beta_r^2}{4} + \frac{1}{4} \quad (10)$$

where β and τ are defined, respectively, as

$$\beta_r = \frac{r_{fus}}{r_w} \quad \text{and} \quad \tau = \frac{\alpha_{eff-s} t}{r_w^2} St_{ps} \quad (11)$$

Equation (10) was also used to analytically predict the radius of fusion. This equation is compared with the experimentally determined radius of fusion values using the conduction model and the heat balance analysis. The result is also presented in Figure 2. The result of the heat balance integral method agrees with the data. The heat balance integral method considers an instantaneous change of the surface temperature with no liquid superheat.

Effective Thermal Conductivity Model

The effective thermal conductivity of copper foam saturated with frozen eicosane can be estimated using models developed for porous media systems. These predictions will be compared with the effective thermal conductivity predicted from the experimental results.

Various models and formulae have been proposed for the prediction of effective thermal conductivity for porous systems. All of these models estimate the thermal conductivity as a function, by combining the individual thermal conductivities of each component and the volume content of each phase, often characterized in terms of system porosity. Furthermore, some models take additional parameters such as the shape of the solid particles, the orientation and the distribution of the particles, and the contact resistance between particles into consideration when evaluating the effective thermal conductivity.

The mechanism of heat transfer in porous materials is complicated by the specific geometric irregularities of the microstructure. In such materials, heat transfer through a saturated porous medium is generally due to conduction, radiation, and convection. However, if the temperature levels are below 250°C, the contribution of the radiation is practically null [23, 24].

Under these circumstances, the only significant mechanism of heat transfer is that of conduction. Consequently, the effective thermal

conductivity of the saturated porous material considered is defined as the relation between the flow of heat and the temperature gradient using Fourier's law.

The estimation of effective thermal conductivities has been studied extensively. Starting with the work of Maxwell [25], heat conduction in fully saturated porous material has been studied in detail over the past several decades. Kaviany [26] has provided an extensive review of the available literature on the subject along with a number of correlations and their range of applicability. Several good reviews of the relevant effective thermal conductivity have been made. These models are described in this section.

There are six models used to compare the thermal conductivity of the copper foam saturated with frozen eicosane. These models were developed for porous media systems. These predictions will be compared with the effective thermal conductivity evaluated from the experimental results.

Model 1: In general, the effective thermal conductivity of a porous medium can be predicted based on the geometry of the media. The effective thermal conductivity, $k_{\text{eff-a}}$, is the volumetric weighted arithmetic mean of the respective thermal conductivities of the porous material (k_{por}) and the solid (k_s) as [27]

$$k_{\text{eff-a}} = (1 - \varphi)k_{\text{por}} + \varphi k_s \quad (12)$$

Model 2: The effective thermal conductivity ($k_{\text{eff-h}}$) can be predicted based on the weighted mean of the two individual thermal conductivities as [28]

$$\frac{1}{k_{\text{eff-h}}} = \frac{1 - \varphi}{k_{\text{por}}} + \frac{\varphi}{k_s} \quad (13)$$

Model 3: For practical purposes, the thermal conductivity k_{eff} can be predicted by the weighted geometric mean of, k_{por} and k_s , defined by [29]

$$k_{\text{eff}} = k_{\text{por}}^{1-\varphi} k_s^\varphi \quad (14)$$

Model 4: Bauer [30] derived an equation that is applicable for randomly distributed spherical inclusions in a medium. The equations for the Bauer models for both regions are

$$k_{\text{eff-s}} + \varphi(k_{\text{por}} - k_s) \left(\frac{k_{\text{eff-s}}}{k_{\text{sol}}} \right)^n - k_{\text{por}} = 0 \quad (15)$$

where the values of n are between a minimum value of 0.02 and a maximum value of 0.34.

Model 5: For high k_{por}/k_s ratio, Kumer and Chaudhary [31] predicted effective thermal conductivity based on a thermal resistance model using

$$k_{eff-s} = (1 - \varphi)k_H + \varphi k_L - \varphi(1 - \varphi)(k_L k_H)^n \quad (16)$$

where the value of n is between 0.5 and 1, and k_H and k_L are defined, respectively, as

$$k_H = k_{por} \exp\left(\frac{k_s}{k_{por}} - 1\right) \varphi$$

$$k_L = k_s \exp\left[-\left(\frac{k_s}{k_{por}} - 1\right)(1 - \varphi)\right] \quad (17)$$

Model 6: Calmidi and Manajan [32] modeled metal foam consisting of dodecahedron-like cells with 12–14 pentagonal or hexagonal faces. The edges of the cells in the model are formed by individual fibers, and the lumping of material at the points of intersection of the fibers is considered in the structure by a square region. Because the structure is periodic, it is convenient to consider a unit cell (Fig. 3).

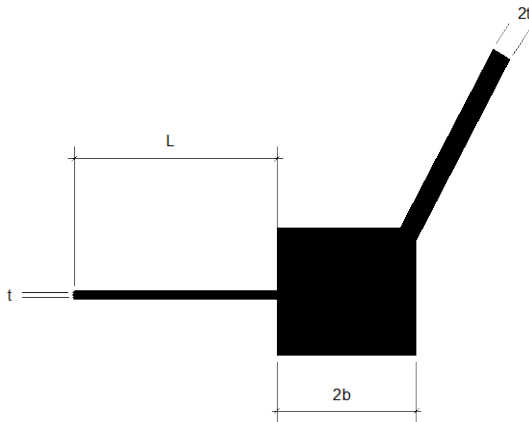


Figure 3. Unit cell representative

Calmidi and Manajan expressed the effective thermal conductivity as

$$k_{eff-s} = \left[\frac{2}{\sqrt{3}}(A + B + C)\right]^n \quad (18)$$

where A , B , and C are defined as

$$\begin{aligned}
 A &= \frac{\frac{t}{L}}{k_s + \left(1 + \frac{b}{L}\right) \frac{(k_{\text{por}} - k_s)}{3}}; \\
 B &= \frac{\left(1 - \frac{t}{b}\right) \left(\frac{b}{L}\right)}{k_s + \frac{2}{3} \left(\frac{b}{L}\right) (k_{\text{por}} - k_s)}; \\
 C &= \frac{\frac{\sqrt{3}}{2} - \frac{b}{L}}{k_s + \frac{4}{3\sqrt{3}} \left(\frac{t}{L}\right) (k_{\text{por}} - k_s)}
 \end{aligned} \tag{19}$$

In Eq. (18), the value of n depends on the porosity, fluid, and the porous material. The n value may vary between -1 and -0.25 . In our case, the dimensions of the copper foam material were $t = 0.012$ cm, $b = 0.096$ cm, and $L = 0.198$ cm. It should be noted that $2L$ is the total distance between two intersections.

EFFECTIVE THERMAL CONDUCTIVITY PREDICTION

If the fusion radius is known, Eqs (6) and (10) may be utilized to estimate the effective thermal conductivity of solid copper foam saturated with eicosane. These results are shown in Figure 4. Utilizing the experimental values of the radius of fusion, both the conduction and heat balance model's effective thermal conductivity predictions agree with each other. The trend of the values of effective thermal conductivity are initially low, the values then plateau between 60 minutes and 100 minutes, and after 100 minutes the values drop.

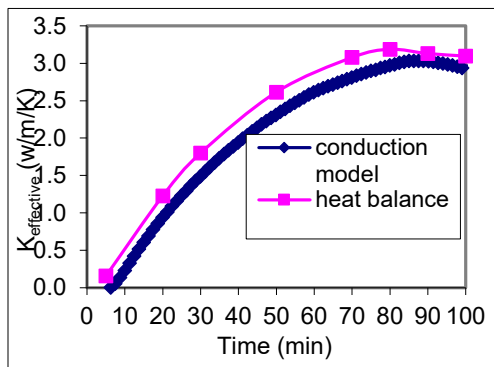


Figure 4. Prediction values of thermal conductivity of solid eicosane.

For the first short period of time during which the liquid eicosane and copper foam cooled from 50°C to the fusion temperature of 36.5°C, the heat transfer is associated with the loss of sensible heat. Next, during the time that the solid eicosane and copper foam cooled from the fusion temperature to 36.5 to 10°C, the heat transfer is associated with the loss of sensible heat as well. This loss of sensible heat is not included in the analysis that was presented in the development of Eqs. (6) and (10).

For times greater than 60 minutes, the temperature everywhere in the system is at or below the fusion temperature and the entire eicosane is solidified. Based on the experimental measurements, the thermal conductivity presented in Figure 4 for times between 60 minutes and 100 minutes is selected for the effective thermal conductivity of copper foam saturated with solid eicosane, because the effective thermal conductivity of solid eicosane does not change significantly with temperature. The value was selected to be near the peak of the effective conductivity curve, observed at $t \approx 85$ minutes, with a value of 3.06 W/m·K.

There were six models used to estimate the effective thermal conductivity of the frozen eicosane/copper-foam system. The results of model predictions are compared with the experimental measurements in Table 3. As mentioned earlier, the value of n in the prediction models 4, 5, and 6, is highly dependent on the porosity, geometry, and thermal conductivities of the porous media. The results of predictions and measurements are presented in Table 3.

Model	1	2	3	4		5		6	Expt. Value
n values	NA	NA	NA	0.34	0.02	0.5	1	-0.31	NA
k_{eff} (W/m·K)	20.4	0.44	0.59	0.49	3.53	7.76	4.88	3.14	3.06

As expected, Models 1 and 2 predict the highest and the lowest value of the effective thermal conductivity, respectively. Models 3 and 5 predict values of thermal conductivity outside the range comparable with this experiment. Model 3 predicts a value of effective thermal conductivity that is too low in comparison to the experimental value and likewise, the values for Model 5 are too high to be comparable with the experimental value of effective thermal conductivity. Models 4 and 6 provide values that are comparable with the experimental value of the effective thermal conductivity. The best result was obtained from Model 6. In the effective conductivity Model 6, a value of n equal to -0.31 resulted in the best match to the experimental average value. The discrepancy between this model (3.14 W/m·K) and the value of the

effective thermal conductivity (3.06 w/m·K) is less than 3%. Model 6 considers the porosity and the geometry of the porous material (copper foam).

UNCERTAINTY ANALYSIS

Consider a general case in which an experimental result, R , is a function of J variables X_j . Then an estimate of the uncertainty in the calculated result (δR), based on a constant-odds formulation, is given by [33]

$$\delta R = \left[\left(\frac{\partial R}{\partial X_1} \delta X_1 \right)^2 + \left(\frac{\partial R}{\partial X_2} \delta X_2 \right)^2 + \dots + \left(\frac{\partial R}{\partial X_J} \delta X_J \right)^2 \right]^{1/2} \quad (20)$$

where $\partial R / \partial X_j$ is the partial derivative of R with respect to X_j and δX_j is the uncertainty of X_j . In many engineering cases, R can be expressed as a product string. In such cases, the relative uncertainty of R is expressed as [34, 35]

$$\frac{\delta R}{R} = \left[\left(a \frac{\delta x_1}{x_1} \right)^2 + \left(b \frac{\delta x_2}{x_2} \right)^2 + \dots \right]^{1/2} \quad (21)$$

Utilizing Eq. (20), the uncertainty in the radius of fusion for freezing and can be expressed as

$$\delta r_{\text{fus}} = \left[\left(\frac{\partial r_{\text{fus}}}{\partial Q_1} \delta Q_1 \right)^2 + \left(\frac{\partial r_{\text{fus}}}{\partial Q_2} \delta Q_2 \right)^2 \right]^{1/2} \quad (22)$$

The uncertainties of Q_1 and Q_2 , utilizing Eq. (21), are defined as

$$\begin{aligned} \delta Q_1 &= Q_1 \left[\left(\frac{\delta \dot{m}}{\dot{m}} \right)^2 + \left(\frac{\delta \Delta T_{\text{meter}}}{\Delta T_{\text{meter}}} \right)^2 \right]^{1/2} \\ \delta Q_2 &= Q_2 \left[\left(\frac{\delta \Delta T_{\text{TC}}}{\Delta T_{\text{TC}}} \right)^2 \right]^{1/2} = Q_2 \frac{\delta \Delta T_{\text{TC}}}{\Delta T_{\text{TC}}} \end{aligned} \quad (23)$$

where Q_1 is the incremental heat transfer to the system from the cooling/heating water flowing in tubes for a given time step, Q_2 is the total heat transfer to each component from the working fluid, $\delta \dot{m} / \dot{m}$ is the relative uncertainty for the mass flow rate of water, $\delta \Delta T_{\text{meter}} / \Delta T_{\text{meter}}$ is the uncertainty of the temperature difference between inlet and outlet of the water flow, and $\delta \Delta T_{\text{TC}} / \Delta T_{\text{TC}}$ is the uncertainty of the temperature differences measured with thermocouples.

The ΔT_{TC} was measured by thermocouples (0.005-inch diameter, OMEGA TT-K-36, type-K thermocouple). In estimating the relative uncertainty, $\delta \Delta T_{\text{TC}} / \Delta T_{\text{TC}}$, thermocouple manufacturer and the data acquisition/control (HP model 3852A) specifications were taken into

account. These estimates indicated that the thermocouple uncertainty is temperature dependent. Results of Eq. (22) are presented in Figure 5.

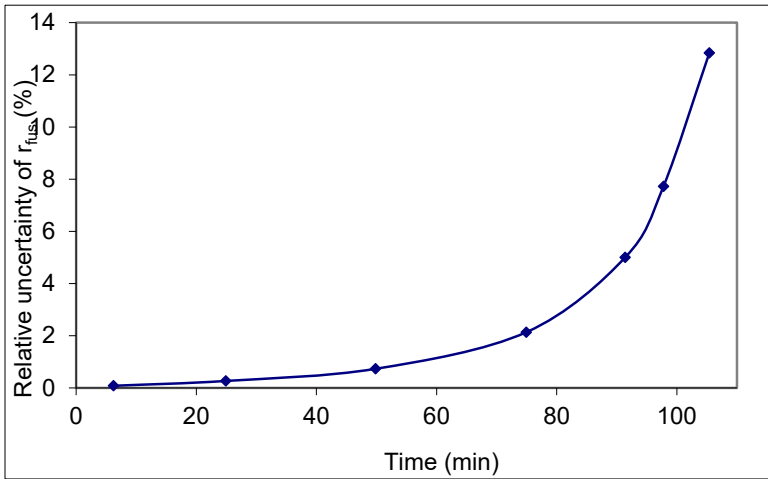


Figure 5. Radius of fusion uncertainty (porous freezing).

This figure presents the uncertainty of the radius of fusion with respect to time. In this figure, as expected at $t = 0$, the uncertainty with respect to the radius of fusion is zero (at the wall radius), and as time progressed, the uncertainty of radius of fusion increased because of an increase in uncertainties of the cumulative heat transfer (Q_1 and Q_2) and the fact that, as the test progresses, r_{fus} decreases, approaching zero for large times.

The only two uncertainties associated with the thermal conductivity are the uncertainties of the radius of fusion and of the temperature-difference measurements obtained with thermocouples. The relative thermal conductivity uncertainty ($\delta k/k$) then, from Eq. (22), can be expressed as

$$\delta k = \left[\left(\frac{\partial k}{\partial r_{fus}} \delta r_{fus} \right)^2 + \left(\frac{\partial k}{\partial \Delta T_{TC}} \delta \Delta T_{TC} \right)^2 \right]^{1/2} \quad (24)$$

where $\partial k / \partial r_{fus}$ is the partial derivative of k with respect to r_{fus} , δr_{fus} is the uncertainty of r_{fus} , $\partial k / \partial \Delta T_{TC}$ is the partial derivative of k with respect to ΔT_{TC} , and $\delta \Delta T_{TC}$ is the uncertainty of ΔT_{TC} .

Utilizing Eq. (24), the uncertainty of the thermal conductivity is predicted. Table 4 presents a typical relative uncertainty for porous thermal conductivity uncertainty. As expected, because thermal

conductivity was not very sensitive to changes of radius of fusion and temperature ($\partial k / \partial r_{\text{fus}}$ and $\partial k / \partial \Delta T_{\text{TC}}$ almost constant), the thermal conductivity relative uncertainty did not change significantly with time (3 to 8% variation).

Table 4. Uncertainty of the thermal conductivity					
Time (min)	δQ_1 (kJ)	δQ_2 (kJ)	$\delta \Delta T_{\text{TC}} / \Delta T_{\text{TC}}$ (%)	$\delta r_{\text{fus}} / r_{\text{fus}}$ (%)	$\delta k / k$ (%)
97.7	8.35	0.91	0.48	7.73	3.04

CONCLUSION

A detailed experimental and analytical study was carried out to evaluate the effective thermal conductivity of a solid/liquid phase-change thermal energy storage system that includes porous metal foam. The PCM and metal foam were contained in a vertically oriented test cylinder that was cooled or heated at its outside boundary, resulting in radially inward freezing or melting, respectively. The porous material used in this experiment (copper foam with porosity of 95%) was intended to minimize the insulating effect of this thermal resistance layer. The PCM was 99% pure eicosane, with a melting temperature of 36.5°C. Eicosane was chosen as the PCM, because its fusion temperature is slightly higher than the ambient temperature. The test vessel system is composed of copper, aluminum, insulation, and acrylic materials whose properties are shown in Table 1. A constant temperature bath of demineralized water was used to supply heating/cooling to the copper heat exchange tubes. The results of this study were discussed in terms of the effectiveness of the metal matrix as a heat transfer enhancement device.

As the PCM freezes, the solid/liquid interface moves inward from the surface of the test cylinder, and a thermal resistance layer is built up, resulting in reduced the heat transfer between the system to be cooled and the PCM. The experimental results were used in the heat conduction and heat balance integral methods to evaluate the effective thermal conductivity of porous copper foam saturated with eicosane. Furthermore, six analytical models were used to predict the effective thermal conductivity. In the effective conductivity model, a value of n equal to -0.31 resulted in the best match to the experimental average value of the thermal conductivity. The discrepancy between this model (3.14 W/m·K) and the value of the effective thermal conductivity (3.06 W/m·K) is less than 3%, and the thermal conductivity relative uncertainty did not change significantly with time (3 to 8% variation) as shown in Table 3. This model considered not only the porosity but also the

geometry of the porous materials. The only two uncertainties associated with the thermal conductivity are the uncertainties of the radius of fusion and of the temperature difference measurements obtained with thermocouples using Eq. (24), and these values are shown in Table 4. The result for the effective thermal conductivity of porous copper foam saturated with eicosane is determined through experimental analysis using the heat conduction and heat integral balance method. The results of each of these experimental values of the thermal conductivity match as shown in Figure 4. Model 6 meets the requirements for analytically predicting the value of the thermal conductivity as shown in Table 3.

ACKNOWLEDGMENTS

This project would not have been possible without the help and support of the Gibson Fellowship at Southern Utah University. Their contributions included providing funding for undergraduate research. The undergraduate research was also partially funded by the NASA Utah Space Grant Consortia.

REFERENCES

- [1] Viskanta R., Bathelt A.G., and Hale N.W., "Latent heat-of-fusion energy storage: experiments on heat transfer during solid-liquid phase change," *Proceedings of the Third Miami Conference on Alternative Energy Sources, December 1980*.
- [2] Weaver J.A., "*Solid-Liquid Phase Change Heat Transfer in Porous Media*" MSME Thesis, Purdue University, May 1985.
- [3] Qian J., Li Q., Yu K., and Xuan Y., "A novel method to determine effective thermal conductivity of porous materials," *Science in China Series E: Technological Sciences* 47 (2004) 716-724.
- [4] Wang M., and Pan N., "Modeling and prediction of the effective thermal conductivity of random open-cell porous foams," *International Journal of Heat and Mass Transfer* 51 (2008) 1325-1331.
- [5] Mendes A.A., Ray S., and Trimis D., "A simple and efficient method for the evaluation of effective thermal conductivity of open-cell foam-like structures," *International Journal of Heat and Mass Transfer*, 66 (2013) 412-422.

- [6] Xiao X., Zhang P., and Li M., “Effective thermal conductivity of open-cell metal foams impregnated with pure paraffin for latent heat storage,” *International Journal of Thermal Sciences*, 81 (2014) 94–105.
- [7] Li Z., Sun W.G., Wang G., and Wu Z.G., “Experimental and numerical study on the effective thermal conductivity of paraffin/expanded graphite composite,” *Solar Energy Materials and Solar Cells*, 128 (2014) 447–455.
- [8] Wang C., Lin T., Li N., and Zheng H., “Heat transfer enhancement of phase change composite material: copper foam/paraffin,” *Renewable Energy*, 96A (2016) 960–965.
- [9] Mocini Sedeh M, and Khodadadi J.M., “Thermal conductivity improvement of phase change materials/graphite foam composites,” *Carbon*, 60 (2013) 117–128.
- [10] Asakuma Y., and Yamamoto T., “Effective thermal conductivity of porous materials and composites as a function of fundamental structural parameters,” *Computer Assisted Methods in Engineering and Science*, 20 (2013) 89–98.
- [11] Gruescu C., Giraud A., Homand F., Kondo D., and Do D.P., “Effective thermal conductivity of partially saturated porous rocks,” *International Journal of Solids and Structures*, 44 (2007) 811–833.
- [12] Aurangzeb D., “*Prediction of Effective Thermal Conductivity of Fluid Saturated Porous Media: in situ Thermo Physical Measurements*,” Ph.D. Dissertation in Physics, Quaid-i-Azam University, Islamabad, Pakistan, 2009.
- [13] Imran M., “An experimental study of thermal and thermohaline convection in saturated porous media,” *Utrecht Studies in Earth Sciences 043*, Dissertation, Utrecht University, Utrecht, Netherlands, 2013. Accessed on November 9, 2023, at <https://dspace.library.uu.nl/handle/1874/285288>.
- [14] Siahpush A., “*Performance Enhancement of Solid/Liquid Phase-Change Thermal Energy Storage Systems Through The Use of A High Conductivity Porous Metal Matrix*,” Ph.D. Dissertation, University of Idaho, Idaho Falls, 2001.

- [15] Incropera F.P., and Dewitt D.P, *Fundamentals of Heat and Mass Transfer*, John Wiley & Sons, New York, 1990.
- [16] Hale, D.V., Hoover, M.J., and O'Neill, M.J., *Phase Change Handbook*, NASA Contractor Report, NASA-CR-61363, September 1971.
- [17] Poulidakus, D., *Conduction Heat Transfer*, Prentice Hall, New Jersey, 1994.
- [18] Sparrow E.M., and Broadbent J.A., "Freezing in a vertical Tube," *Journal of Heat Transfer*, 105 (1983) 217–225.
- [19] Goodman T.R., "The heat-balance integral and its application to problems involving a change of phase," *ASME Transactions*, 80 (1958) 335–342.
- [20] Goodman T.R., "Application of integral methods to transient nonlinear heat transfer," *Advances in Heat Transfer*, 1 (1964) 52–122.
- [21] Lunardini V.J., "Phase change around a circular cylinder," *ASME Journal of Heat and Mass Transfer*, 103 (1981) 598-600.
- [22] Crowley A.B., "Numerical solution of Stefan problems," *International Journal of Heat Mass Transfer*, 21 (1978) 215–219.
- [23] Hill F.B. and Wilhelm R.H., "Radiative and conductive heat transfer in quiescent gas solid beds," *AICHE Journal* 5 (1959) 486.
- [24] Luikov A.V., *Heat and Mass Transfer in Capillary Porous Bodies*, Pergamon Press, Oxford, 1964.
- [25] Maxwell J.C., *A Treatise on Electricity and Magnetism*, Vol. 1, Oxford University Press, 1891, reprinted by Dover, New York, 1954.
- [26] Kaviany M., *Principles of Heat Transfer in Porous Media*, Springer-Verlag, New York, 1995.
- [27] Nield D.A. and Bejan A., *Convection in Porous Media*, Springer, New York, 1999.

- [28] Nield D.A., "Estimation of the stagnant thermal conductivity of saturated porous media," *International Journal of Heat and Mass Transfer* 34 (1991) 1575–1576.
- [29] Tong X., Khan J.A., and RuhulAmin M., "Enhancement of heat transfer by inserting a metal matrix into a phase change material," *Numerical Heat Transfer, Part A, Applications*, 30 (1996) 125–141.
- [30] Bauer T.H., "A general approach toward the conductivity of porous media," *International Journal of Heat and Mass Transfer*, 36 (1993) 4181–4191.
- [31] Kumar V., and Chaudhary D.R., "Prediction of effective thermal conductivity of two phase porous material using resistor model," *Indian Journal of Pure & Applied Physics*, 18 (1980) 984–987.
- [32] Calmidi V.V., and Manajan R.L., "The effective thermal conductivity of high porosity fibrous metal foams," *Transactions of the ASME*, 121 (1999). 466-471.
- [33] Coleman H.W., and Steele W.G., *Experimentation and Uncertainty Analysis for Engineers*, John Wiley and Sons, New York, New York, 1989.
- [34] Moffat R.J., "Contributions to the theory of single-sample uncertainty analysis," *Journal of Fluids Engineering*, 104 (1982) 250–259.
- [35] Moffatt R.J., "Describing the uncertainties in experimental results," *Experimental Thermal and Fluid Science*, 1 (1988) 3–17.

Lumped Method Transient Conduction Heat Transfer

**Sergio Reyescordova, Kaden Allred, Ethan Arnold,
William Miller, Ali Siahpush**
Southern Utah University

Abstract

In this experiment, we tested multiple configurations of aluminum and examined their validity as a lumped system. For a material to meet the requirements of a lumped system, it requires a uniform temperature throughout the material. To test this validity, each configuration was submerged in hot water and then immediately cooled in ice water. The experimental change in temperature of the configurations was recorded and used with the log-incomplete response of the temperature change to determine the time constant. The time constant was used with the lumped system analysis heat transfer equations to evaluate the convection heat transfer coefficient of the fluid. Next, the convection heat transfer coefficient was used to evaluate a Biot number, which must be less than or equal to 0.1 for the lumped system analysis to be valid. The Biot numbers of each trial were found to be less than 0.1, verifying that all the configurations can be considered lumped systems.

NOMENCLATURE	
Symbol	Description
Asurf	Surface area (m^2)
Bi	Biot number
cp	Specific heat ($\frac{J}{kg.K}$)
\dot{E}	Rate of energy transfer (W)
h	Heat transfer coefficient ($\frac{W}{m^2.K}$)
k	Thermal conductivity ($\frac{W}{m.K}$)
Lc	Characteristic length (m)
m	Mass (kg)
ρ	Density ($\frac{kg}{m^3}$)
P	Proportion of T^* between T_i and T_∞ ($^\circ C$)
t	Time (s)
t^*	Time at proportion P (s)
T^*	Temperature at proportion P ($^\circ C$)
T_i	Initial temperature ($^\circ C$)
T_∞	Temperature of fluid ($^\circ C$)
$T(t)$	Temperature at time t ($^\circ C$)
τ	Time constant (s)
V	Volume (m^3)

INTRODUCTION

Evaluating the heating and cooling rate of different shapes and sizes of materials can be very complicated. Fortunately, if certain conditions are met, a lumped method [1] can be used to predict and calculate these different temperature rates. To use this method, the temperature has to be uniform throughout the material and the Biot number has to be less than 0.1. If these are met then the lumped method can be used to predict the heat transfer through complicated figures.

The lumped system analysis has been tested in other types of experiments. Gaeckle et al. [1] used the lumped system analysis to analyze heat transfer from aluminum, glass, and plastic bottles and compared the experimental values to the theoretical values. Mishra and Kumar [2] estimated the temperature profile of three different geometries of two different materials using lumped analysis. In addition to its use in experiments such as these, the lumped method is also used in several different industries to accomplish various goals including finding the heat transfer characteristics of lithium-ion battery cells and radiative heat transfer [3], jet impingement heat transfer for quick cooling systems [4],

the process of supercooling materials [5], and predicting the heating requirements for conventional greenhouses in cold climates [6].

The objective of this undergraduate research at Southern Utah University is to verify whether this procedure is a cost-effective way to allow students to correctly learn and experiment using the lumped method. This validation was performed by measuring the temperature change for three different small aluminum configurations: a cylinder, sphere, and plates (two different thicknesses). By evaluating and verifying the Biot number, we aimed to determine whether a lumped method can be assumed for all three configurations and their heat transfer processes.

THEORY

The first law of thermodynamics states [7]

$$\dot{E}_{in} - \dot{E}_{out} = \dot{E}_{system} \quad (1)$$

where \dot{E}_{in} is the rate of energy into the system (W), \dot{E}_{out} is the rate of energy out of the system (W), and \dot{E}_{system} is the rate of energy change of the system (W). In a lump system analysis, only the convection heat transfer between the material and the surrounding fluid is considered. In the case of heating the solid, the heat transfer in the system can be expressed as [7]

$$hA_{surf}(T_{\infty} - T(t)) = m_{al}c_{pal} \frac{d(T(t) - T_{\infty})}{dt} \quad (2)$$

Where h is the heat transfer coefficient of the fluid ($\frac{W}{m^2.K}$), A_{surf} is the surface area of the aluminum (m^2), T_{∞} is the temperature of the fluid ($^{\circ}C$), $T(t)$ is the temperature of the aluminum ($^{\circ}C$), m_{al} is the mass of the aluminum (kg), c_{pal} is the specific heat of the aluminum ($\frac{J}{kg.K}$), and t is time (s). The term on the left side of Eq. (2) is the convection heat transfer from the fluid in the case of heating the material, and the term on the right side is the change in energy of the system/aluminum. Equation (2) can be solved and the result is [8]

$$\frac{T(t) - T_i}{T_i - T_{\infty}} = e^{-\frac{t}{\tau}} \quad (3)$$

where T_i is the initial temperature ($^{\circ}C$) of aluminum, and τ is the time constant (s). The time constant is a characteristic time of a system indicating how fast the system reaches the steady state when subjected to a step input [7], and is presented as

$$\tau = \frac{\rho V c_{pal}}{hA_{surf}} \quad (4)$$

where ρ is the density ($\frac{kg}{m^3}$) and V is the volume m^3 , and A_{surf} is the surface area of the material (m^2). To use the lumped method, τ has to be constant and the Biot number (Bi), must be less than 0.1. The Biot number, Bi, is defined as [1]

$$Bi = \frac{hL_c}{k_{al}} \quad (5)$$

where L_c is the characteristic length (m), and K_{al} is the thermal conductivity of aluminum ($\frac{W}{m.K}$). The characteristic length for each configuration is defined as [7, p. 240]

$$L_c = \frac{V}{A_{surf}} \quad (6)$$

As stated, τ is constant in the lumped method. From Eq. (3), τ varies for each time step for exponential decay. A valid solution is to use the logarithm of the incomplete response, P , to determine a constant τ . P identifies the temperature between T_i and T_∞ that represents how close the temperature of the material is to its final temperature as [7]

$$\frac{T^*(t^*) - T_i}{T_i - T_\infty} = -(1 - e^{-\frac{t^*}{\tau}}) = P \quad (7)$$

where superscript * notes that these are exact temperatures and times found in the experimental data when the chosen P is achieved. To estimate a constant τ , P is assigned to be 0.5 and 0.632 as the slope is the steepest between these two values. With a P value determined, $T^*(t^*)$ can be calculated and its corresponding predicted time, t^* , is determined in the experimental data. The corresponding time, t^* , is determined by using linear interpolation. After finding t^* , τ can be evaluated using as

$$\tau = \frac{-t^*}{\ln(1 - P)} \quad (8)$$

With τ determined for the chosen P , a new $T(t)$ can now be determined by using Eq. (3). To determine a Biot number, the calculated τ is used to evaluate the heat transfer coefficient, h as

$$h = \frac{\rho V c_{p_{al}}}{\tau A_{surf}} \quad (9)$$

This calculated h is used in Eq. (5) to determine a Biot number and verify whether this is a valid lumped system.

MATERIALS

- 4-channel data logger (https://www.amazon.com/Instruments-Thermometer-Thermocouple-Temperature-K-Thermocouple/dp/B00M9Z3JJ8/ref=sr_1_3?crid=3CMW0RCKF6H6T&keywords=4%2Bchannel%2Btemperature%2Bdata%2Blogger&qid=1697408782&sprefix=4%2Bchannel%2Bdata%2Caps%2C141&sr=8-3&th=1)
- 1-in-diameter aluminum sphere
- 8×8 -in \times 1/16-in aluminum sheet
- 8×8 -in \times 1/4-in aluminum sheet
- 1-in-height \times 1-in-diameter aluminum cylinder
- K-type thermocouple
- Cooler
- Ice packs
- Small electric heater stove
- Stock pot

The experimental set-up with all the materials is shown in Figure. 1. Only the set-up for the testing of the aluminum cylinder is shown. For the other configurations, the experimental set-up was identical.

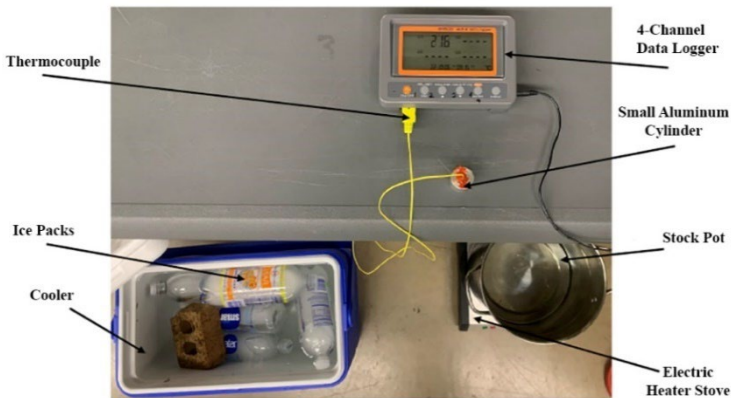


Figure 1. Materials and set-up for the experiment with the small aluminum cylinder

PROCEDURE

1. Collect all the components for the experiment.
2. Fill stock pot with water and begin heating.

3. Fill cooler with water and ice packs.
4. Wait until the temperatures of the volumes of hot and cold water reach steady state.
5. Plug in thermocouples to data loggers.
6. Start recording on the data logger.
7. Put aluminum cylinder into hot water for 3 ½ minutes without letting it touch the sides or bottom of the stock pot.
8. Put aluminum cylinder into cold water for 3 ½ minutes without letting it touch the ice or sides and bottom of the cooler.
9. Remove aluminum cylinder from cooler and stop recording data.
10. Repeat steps 4–9 for other configurations.

RESULTS AND DISCUSSION

Using Eq. (7) with P values of 0.5 and 0.632, the experimental data was compared with the predicted temperatures. As stated in the theory, these two values are used because the slope is the greatest. This provides the most accurate results for approximating the exponential change of temperature when it is close to a linear slope. Equation (7) was used to find $T(t^*)$, then t^* , as evaluated from the experimental data using linear interpolation and finally, Eq. (4) was used to get τ . All of the data are summarized in Table 1 for heating and in Table 2 for cooling.

Table 1. Values for $T(t^*)$, t^* , and τ for heating						
Aluminum Object	P = 0.5			P = 0.632		
	T(t^*)	t^*	τ	T(t^*)	t^*	T
1/16-in plate	49.05	24.05	34.70	56.22	33.36	33.37
¼-in plate	50.80	16.94	24.45	58.24	21.70	21.71
1-in sphere	51.75	10.05	14.50	59.26	12.65	12.65
1-in cylinder	49.60	15.33	22.12	57.10	21.30	21.30

Table 2. Values for $T(t^*)$, t^* , and τ for cooling						
Aluminum Object	P = 0.5			P = 0.632		
	T(t^*)	t^*	τ	T(t^*)	t^*	T
1/16-in plate	43.80	20.45	29.51	35.11	29.09	29.10
¼-in plate	44.45	21.61	31.18	35.59	25.12	25.12
1-in sphere	43.15	10.32	14.89	33.13	13.99	13.99
1-in cylinder	36.80	18	25.97	27.72	25.12	25.12

For both the heating and the cooling of each configuration, the temperature over time was plotted. The heating response of the 1/4-inch-thick aluminum plate, 1/16-inch-thick aluminum plate, 1-in-diameter

aluminum sphere, and 1-in-diameter aluminum cylinder are shown in Figures 2–5. The cooling responses of the configurations are shown in Figures 6–8.

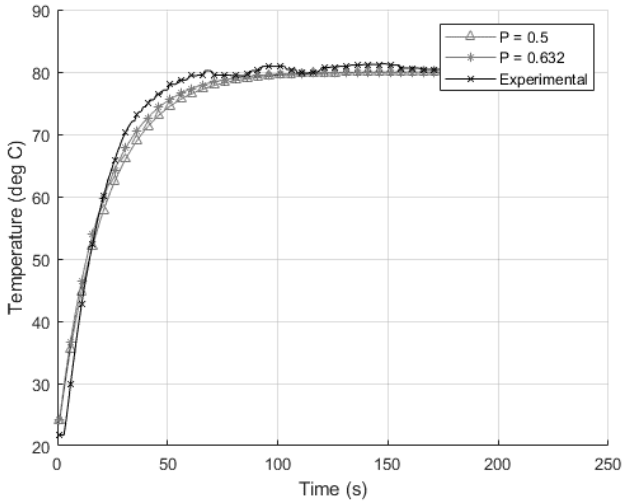


Figure 2. Heating temperature profiles for predicted and experimental data of 1/4-in aluminum sheet.

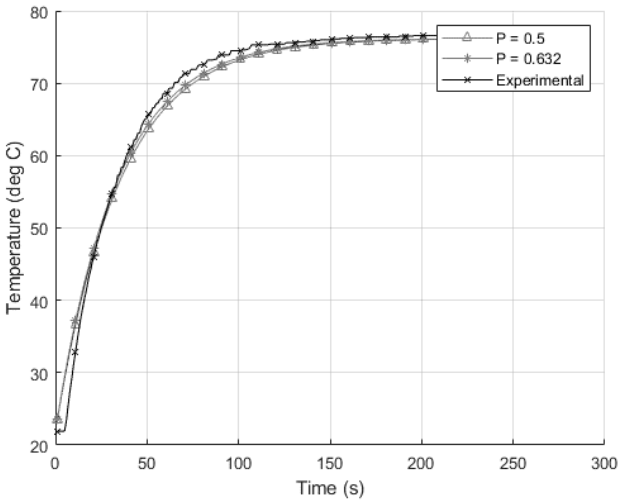


Figure 3. Heating temperature profiles for predicted and experimental data of 1/16-in aluminum sheet.

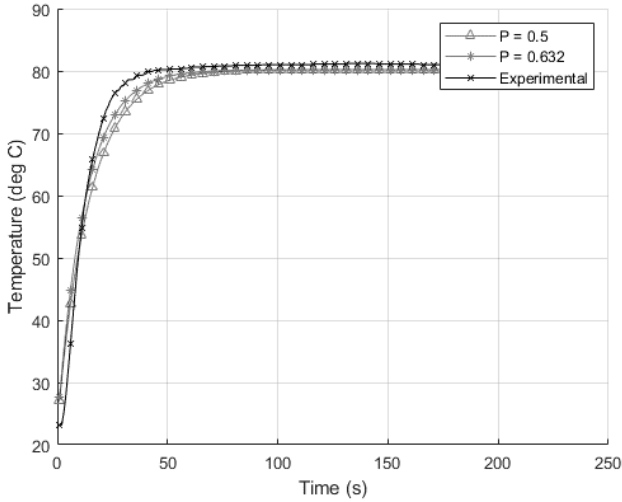


Figure 4. Heating temperature profiles for predicted and experimental data of 1-in aluminum sphere.

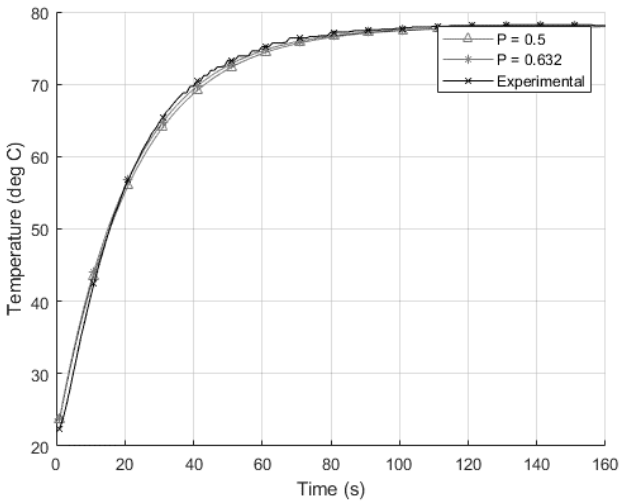


Figure 5. Heating temperature profiles for predicted and experimental data of 1-in aluminum cylinder

In Figure 2, the experimental data for the 1/4-in-thick plate seems to have anomaly increases in temperature that can be seen in three instances. From 60 seconds to 70 seconds, there was a temperature

increase of 0.8°C , which then receded into the curve. At 86 seconds through 109 seconds, the temperature increased by 1.3°C and then returned to the original temperature. At 123 seconds to 155 seconds, the temperature increased by 0.6°C and then returned to the temperature curve. Otherwise, the experimental data shape correlated with the shape of the predicted data curves. The experimental data did not correspond with the predicted curves exactly, as can be seen from 25 seconds through 60 seconds, because the temperatures were much higher than the predicted plots.

In Figure 3, the data gathered for the 1/16-in-thick plate correlated with the predicted temperature except for the time from 40 seconds to about 120 seconds. The data for the sphere (Fig. 4) were higher than the predicted data for the time from 20 seconds to 50 seconds. The margin of difference between the two curves lessened as time went on, but the curves never crossed after 40 seconds.

In Figure 5, the temperature profile seemed to follow the same trend when P was equal to 0.5 and 0.623. The experimental data was below both predicted profiles until the temperature reached 49°C . From 49°C to 56.8°C , the experimental temperature remained between both predicted temperatures. After 56.8°C , the experimental temperature was above both profiles.

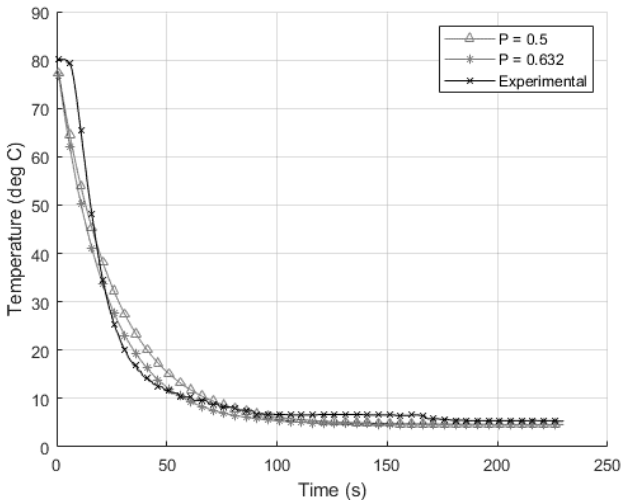


Figure 6. Cooling temperature profiles for predicted and experimental data of 1/4-in aluminum plate.

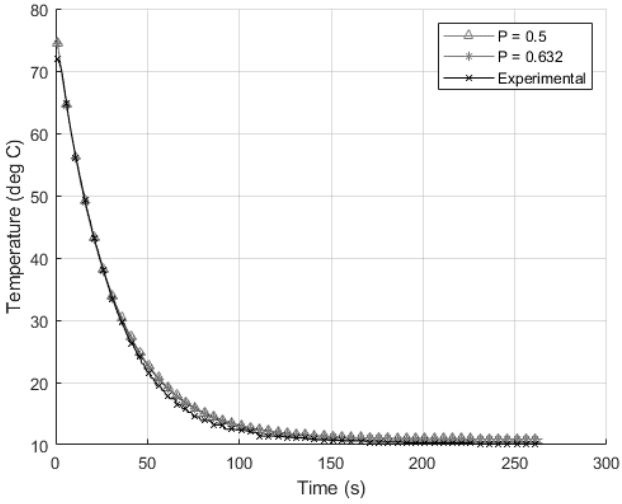


Figure 7. Cooling temperature profiles for predicted and experimental data of 1/16-in aluminum plate.

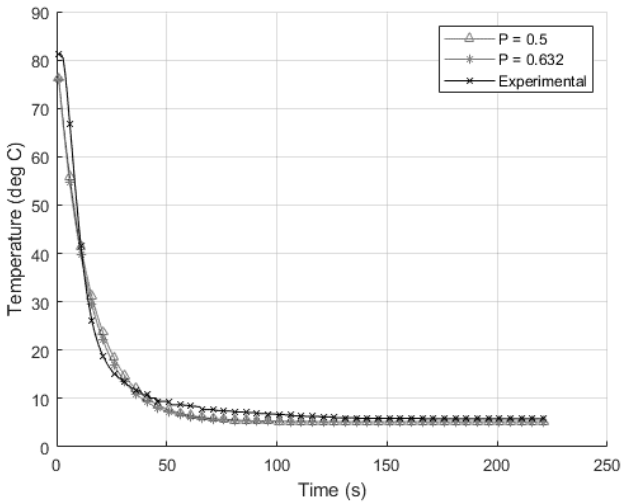


Figure 8. Cooling temperature profiles for predicted and experimental data of 1-in aluminum sphere.

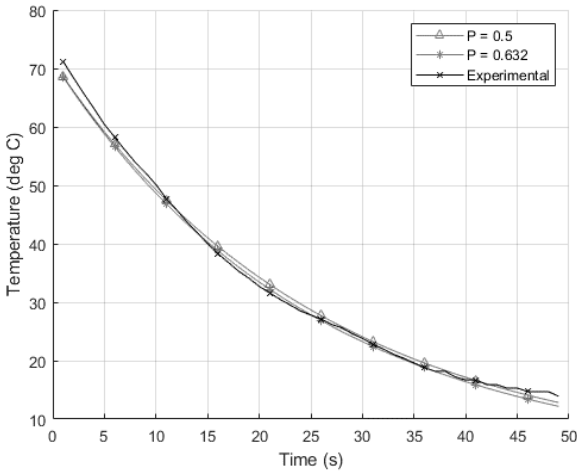


Figure 9. Cooling temperature profiles for predicted and experimental data of 1-in aluminum cylinder.

The data shown in Figure 6 indicate that the experimental data for the 1/4-in-thick plate crossed the predicted temperature data curves multiple times. The first time is at approximately 40 seconds and then crosses back over in between 50 and 60 seconds. The first time the experimental data crossed over the predicted curves it resulted in the experimental data being closer to the 0.632 curve, but after crossing back over, the experimental data were then closer to the 0.5 curve.

Figure 7 resulted in a near-perfect correlation between the experimental and the predicted data curves for the 1/16-in-thick plate. For the aluminum sphere temperature data in Figure 8, the curves are similar to those in Figure 6, in which the experimental data cross the predicted curves. However, the difference between the two figures was that Figure 8 resulted in much closer curves of the experimental data to the predicted data. The experimental data in Figure 9 for the aluminum cylinder reveal a good trend when compared with both P values. The data follow both predicted curves from 12 to 13 seconds and 25 to 36 seconds. In Figures 6 and 8, the predicted data cross the experimental data at the points of 0.5 and 0.632, which shows the close relation that the experimental and predicted data have. Meanwhile, in Figure 7, the predicted curve matches almost exactly the experimental curve.

To validate the results of the experiment, the Biot number must be determined to be under 0.1. As stated in the theory, this validates the use of the lumped method. The first step was calculating the heat transfer

coefficient using Eq. (9) for both cooling and heating trials when P was equal to 0.5 and 0.623, which are seen in Table 3.

Table 3. Heat transfer coefficients (h) of materials ($\frac{W}{m^2 K}$)				
Aluminum object	P = 0.5		P = 0.632	
	Heating	Cooling	Heating	Cooling
1/4-in plate	295.72	231.89	332.97	287.73
1/16-in plate	54.49	244.98	56.65	248.45
1-in sphere	706.45	687.71	809.30	731.81
Cylinder	462.41	393.71	480.14	407.14

Even though the heat transfer coefficients in Table 3 are all different, they are valid. The reason that the h values differ among configurations of the aluminum is the different surface areas. The configurations with larger ratios of volume to surface area had a lower h value. The 1/4-in plate had a surface area-to-volume ratio of 8.5, the ratio for the 1/16-in plate was 32.5, and the sphere and cylinder both had ratios of 6. The 1/16-in plate had the highest ratio of surface area-to-volume and also had the lowest heat transfer coefficient, whereas the sphere and cylinder had the lowest ratio of 6 and also the highest h values. The sphere and cylinder did, however, have different h values despite the same ratio of surface area to volume. This is because the sphere had a larger surface area, which directly impacts the heat transfer coefficient as previously mentioned.

Using the heat transfer coefficients from Table 3, the Biot numbers of each trial are displayed in Table 4. For all the configurations, the Biot numbers was less than 0.1.

Table 4. Biot Numbers (Bi) for the logarithm of the incomplete response				
Aluminum Object	P=0.5		P=0.632	
	Heating	Cooling	Heating	Cooling
1/4-in plate	0.0053	0.0041	0.0060	0.0051
1/16-in plate	0.0003	0.0044	0.0003	0.0044
1-in sphere	0.0537	0.0523	0.0615	0.0557
Cylinder	0.0351	0.0299	0.0365	0.0309

SOURCES OF ERROR

The main error source in this experiment comes from the placement of each configuration in the water for the pot and cooler. It is important to make sure each configuration was suspended in the water and not

touching anything within the containers. In the pot, each aluminum configuration was suspended in the middle of the water so they did not gain any heat transfer from conduction by touching any of the surfaces. For the cooling tests, the cold water contained ice packs to keep the water at a steady temperature. Two of the three cylinders were not touching the ice, just the water, whereas the third cylinder tested was touching the ice. For the plates and the sphere, the configurations either did not touch the ice packs or the edges at all or would rarely tap with the aluminum. The plates and the sphere then have no impact with spikes or outliers in the data because the time touching the ice was always less than 1 second. When the cylinders touched the ice, it resulted in heat being transferred from the cylinder to the water via convection and to the ice by conduction. Although the error was minimal, this cylinder still contributed larger-than-accurate temperature drops to the average data.

The thermocouples used also provided a slight source of error. The plates had their thermocouple attached to the center of one side. The cylinders had their thermocouples attached to the center of the top, flat side of them. The spheres had their thermocouple put into the center of them and held in place by the putty. Just as the sphere's thermocouple was, the other configurations should have had their thermocouple placed in their center.

CONCLUSIONS

In conclusion, we identified that in the heating phase, the experimental data were slightly higher than the predicted temperature profiles for all configurations. In the cooling phase, the experimental data were between the two predicted temperature profiles. Because the experimental data were minutely different from the predicted temperature profiles and both validations to prove that, we determined that the analysis was applicable. The Biot numbers showed the use of the lump sum analysis and the logarithm of the incomplete response was accurate and applicable. The experiment resulted in an accurate representation of the heat transfer profile for each aluminum configuration and the water for heating and cooling; however, improvements could be made to this experiment to achieve more accurate results. If the pot used in the heating experiment was smaller for the sphere and cylinder and larger for the plates, the overall temperature difference from the bottom of the pot to the top would be negligible for the smaller configurations and the bigger pot would avoid conduction to the plates. For the cooling experiments, a smaller cooler would have the same effect as reducing the size of the pot; similarly, removing the ice

packs from the cooler right before the cylinders were submerged might result in less contact between the cylinders and ice packs.

ACKNOWLEDGMENTS

This project would not have been possible without the help and support of the Department of Engineering and Technology at Southern Utah University. Their contributions included providing the equipment and assistance from faculty. Also, the undergraduate research funding was partially provided by the NASA Utah Space Grant Consortia.

REFERENCES

- [1] G. Gaeckle, J. Liggett, M. Sutadji, and J. Turk, "Experimentation of heat transfer using lumped system analysis," 2015. Retrieved December 12, 2022, from <https://www.csuohio.edu/sites/default/files/36-%202015.pdf>.
- [2] M. Mishra and P. Kumar, "Experimental lumped analysis of different solid geometries," *IOP Conf. Ser.: Mater. Sci. Eng.* vol. 691, pp. 012082, 2019.
- [3] W. Allafi, C. Zhang, K. Uddin, D. Worwood, T.Q. Dinh, P.A. Ormeno, K. Li, and J. Marco, "A lumped thermal model of lithium-ion battery cells considering radiative heat transfer," *Appl. Thermal Eng.*, vol. 143, no. 1, pp. 472-481, 2018.
- [4] T. Marazani, D.M. Madyira, and E.T. Akinlabi, "Investigation of the parameters governing the performance of jet impingement quick food freezing and cooling systems—a review," *Proc. Manufact.*, vol. 8, no. 1, pp. 754-760, 2017.
- [5] T. Davin, B. Lefez, and A. Guillet, "Supercooling of phase change: A new modeling formulation using apparent specific heat capacity," *Int. J. Thermal Sci.*, vol. 147, no. 1, p. 106121, 2020.
- [6] M.S. Ahamed, H. Guo, and K. Tanino, "A quasi-steady state model for predicting the heating requirements of conventional greenhouses in cold regions," *Infor. Process. Agric.*, vol. 5, no. 1, pp. 33-46, 2018.
- [7] A.J.G. Yungus, and A. Cengel, *Heat and Mass Transfer*, New York, McGraw-Hill Education, 2015, p. 27.

[8] D.A. Siahpush, "Lab 3 Procedure," Southern Utah University , Cedar City Utah, 2022.

[9] ES205 Analysis and Design of Engineering Systems, "Experimentally identifying the time constant and convection coefficient of a thermocouple," Rose-Hulman Institute of Technology, Terre Haute, Indiana, 2003.

Studying Natural Convection Through Melting a Slab of Ice

Toby McMurray, Manuel Gaspar, Matthew Bayreder, Slater Emery, and Ali Siahpush

Southern Utah University

ABSTRACT

Natural convection is a complex, but important concept in heat transfer, because it helps explain many of the earth's natural systems. The purpose of this experiment was to study natural convection by melting a slab of ice and comparing the result to an analytical solution. Specifically, the mass flow rate of the melting ice was measured and predicted. The average measured mass flow rate was 280.79 g/hr and the predicted flow rate was 172.56 g/hr. These values exhibited a 62.72% error. This large percent error could be attributed to a multitude of factors including improper enclosure conditions around the ice slab and assumptions associated with the analytical approach

INTRODUCTION

Natural convection, also known as free convection, is an important concept in heat transfer because it helps to explain many of the earth's natural systems such as the rain cycle and sea and land breezes. Natural convection heat transfer upon a surface depends on the geometry and

orientation of the surface, as well as the variation of temperature and thermophysical properties of the fluid [1].

There is copious technical literature and research on the topic of natural convection. Specifically, the Nusselt number, convection heat transfer coefficient, and the Grashof number for different shapes of ice have been studied [2]. The effects of air pressure on natural convection have also been studied [3].

The experiment that was replicated in this paper was described by Adrian Bejan for determining the melting mass flow rate of a slab of ice [4]. The purpose of this experiment was to study natural convection by melting a slab of ice and predicting and measuring its melting mass flow rate.

THEORY

Natural convection occurs when the temperature of the surrounding fluid, in this case air, is different than that of a solid surface. In the case of a cold surface, the air adjacent to the surface is cooled, resulting in an increase in air density. This causes the air to flow downwards, where it can reheat as it mixes with warm air and circulate back upwards. A depiction of this process is shown in Fig. 1.

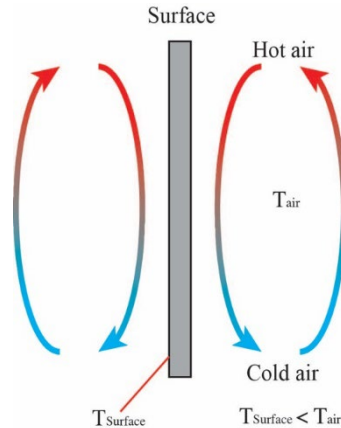


Figure 1. Visualization of airflow due to natural convection.

Natural convection can be studied by melting a vertical slab of ice and measuring the mass flow rate \dot{m} (kg/s). The mass flow rate of the ice can be calculated as [1]

$$\dot{m} = \rho Av \quad (1)$$

where ρ is the density of water (1000 kg/m^3), A is the cross-sectional area (m^2), and v is the airflow velocity (m/s). Because the flow velocity of the melting ice is unknown, Eq. (1) must be modified to determine the mass flow rate for natural convection. The relationship between buoyancy force and viscous force is determined by Rayleigh's number defined as [1]

$$R_{aL} = \frac{g\beta(T_\infty - T_s)L_c^3}{\alpha\nu} \quad (2)$$

where g is the acceleration due to gravity ($9.81 \text{ m}^2/\text{s}$), β is the coefficient of volume expansion ($1/\text{K}$), T_∞ is the temperature of the air sufficiently far from the surface (K), T_s is the temperature of the surface (K), L_c is the characteristic length (m), α is the thermal diffusivity of air (m^2/s), and ν is the kinematic viscosity of the air (m^2/s). In this case, the characteristic length of the ice slab is its height H . For an ideal gas (air), the coefficient of volume expansion β can be determined as [1]

$$\beta = \frac{1}{\frac{(T_\infty + T_s)}{2}} \quad (3)$$

The heat transfer between the surface of the ice slab at the adjacent air, at room temperature, as it descends the surface can be expressed as [4]

$$q''(y) = \rho_w h_s \frac{1}{2} \left(\frac{dL(y)}{dt} \right) \quad (4)$$

Where ρ_w is the density of water (1000 kg/m^3), h_s is the latent heat of the fusion (333.4 J/g for ice), $dL(y)$ is the rate of change of the thickness of the ice slab as a function of height (m), and dt is the change in time (s). The one-half term comes from the fact that the characteristic length is the thickness of the ice slab, although in this case, because of symmetry, only half of the thickness of the ice slab is analyzed where one side is assumed insulated and the other in contact with air [1]. Because velocity can be expressed as the change in distance over the change in time and the area is the product of the width and the height, Eq. (1) can be rewritten as

$$\dot{m} = \rho WH \left(\frac{dL_{ave}}{dt} \right) \quad (5)$$

where W is the width of the ice slab (m), H is the height of the ice slab (m), and L_{ave} is the average thickness of the ice slab (m). The average

ratio of convective to conductive heat transfer based on the average height of the ice slab can be defined by the Nusselt number as [1]

$$\text{Nu}_{\text{ave}} = \frac{h_{\text{ave}}H}{k_{\text{air}}} \quad (6)$$

where h_{ave} is the average convection heat transfer coefficient ($\text{W}/\text{m}^2\cdot\text{K}$), and k_{air} is the thermal conductivity of the air ($\text{W}/\text{m}\cdot\text{K}$). Using Newton's law of cooling, h_{ave} can be expressed as [1]

$$h_{\text{ave}} = \frac{q''}{(T_{\infty} - T_s)} \quad (7)$$

Combining Eqs. (6) and (7), the Nusselt number can be expressed as

$$\text{Nu} = \frac{q''H}{(T_{\infty} - T_s)k_{\text{air}}} \quad (8)$$

Also, using Table 9-1 from reference [1], an approximation for the Nusselt number may be expressed as

$$\text{Nu} = \left\{ 0.825 + \frac{0.387R_{\text{aL}}^{\frac{1}{6}}}{\left[1 + \left(\frac{0.492}{\text{Pr}} \right)^{\frac{9}{16}} \right]^{\frac{8}{27}}} \right\}^2 \quad (9)$$

Where Pr is the Prandtl number that describes the ratio of kinematic viscosity (ν) and thermal diffusivity (α) [1]. Solving for $\frac{dL}{dt}$ in Eq. (4) and substituting it into Eq. (5), the mass flow rate may be expressed as

$$\dot{m} = WH \left(\frac{2q''}{h_s} \right) \quad (10)$$

Solving for q'' in Eq. (8) and substituting it into Eq. (10) can further express the mass flow rate as

$$\dot{m} = \frac{2WH(T_{\infty} - T_s)k_{\text{air}}}{h_s} \quad (11)$$

The properties of air (ρ , C_p , k , α , μ , ν , Pr) at one atmosphere of pressure and a specified temperature can be found using Table A-15 from reference [1]. Note that when determining the properties of air, the average temperature must be used. Also, the properties of air change with pressure. Ideally, the properties of air at the local pressure where the experiment takes place should be considered. However, the properties of

air at one atmosphere pressure can be used without causing any significant error. It is expected that the top of the ice slab will melt faster than the bottom because of the natural airflow as shown in Figure 1. This thinning of the ice causes the ice slab to melt faster over time. Then, it is expected that a higher value for the measured mass flow rate will be seen as compared to the predicted.

EQUIPMENT AND MATERIALS

The materials used in this experiment are listed below. The experimental apparatus that was built to conduct the testing is also shown in Figure 2 and a detailed view of the inside of the enclosure is shown in Figure 3.

- ABS pipe (3-in diameter) with pipe supports
- String
- Baking pan (Fat Daddio's POB-7113 anodized aluminum sheet cake pan (7×11×3 in); <https://www.amazon.sg/Fat-Daddios-POB-10153-Anodized-Aluminum/dp/B001332TBG?th=1>)
- Data logger (4-channel K thermocouple SD card logger, 88598 AZ EB - AZ Instrument Corp.; <https://www.az-instrument.com.tw/en/product-616361/4-Channel-K-Thermocouple-SD-Card-Logger-88598-AZ-EB.html>)
- Two thermocouples (2 pcs K type 0-400°C temperature sensor thermocouple probe 3 meter, HuaHuiYuan; <https://www.amazon.com/0-400%E2%84%83-Temperature-Sensor-Thermocouple-Probe/dp/B071FJ9HJQ>)
- Freezer
- 500-mL graduated cylinder (plastic graduated cylinder, 500mL, Class B – stable hexagonal base, premium polypropylene, Eisco Labs; <https://www.amazon.com/500mL-Graduated-Cylinder-Polypropylene-Graduation/dp/B00LV3ZFF0>)

PROCEDURE

The experimental setup consisted of a wood and acrylic enclosure as shown in Figures 2 and 3. Inside the enclosure were two half pipe pieces placed opposite of each other and angled to 55 degrees above horizontal to collect water. A 15 × 10 × 0.39-in ice slab was then suspended vertically from a crossbar such that the ice drips into the pipes as it melts.

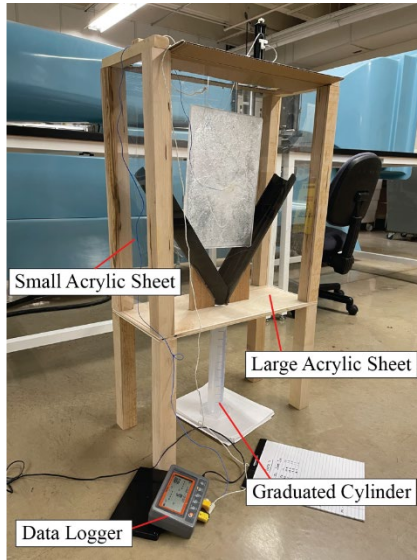


Figure 2. Experimental apparatus used to conduct testing.

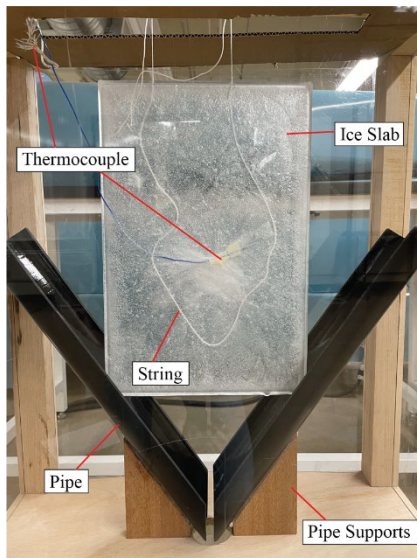


Figure 3. Internal view of the experimental apparatus.

The pipes funnel the water into a graduated cylinder. The volumetric flow rate was measured by recording the level of water in the graduated cylinder over time. Once the experimental apparatus was built, the experiment was conducted as follows.

1. Pour 500 mL of water into the baking pan. Note that 488 mL is equivalent to a half centimeter of thickness. For the first layer, 500 mL was used to offset the loss of water during the removal process from the baking pan.
2. Place the baking pan with the water into a freezer set to -15°C , which was selected because it was the highest temperature setting on the freezer (closest to 0°C). Ensure that the pan is level so that the water will freeze into a uniform thickness.
3. Loop the string into the water such that ~ 6 inches on each end are hanging out of the water and the loop of the string is floating in the water as seen in Figure 4.

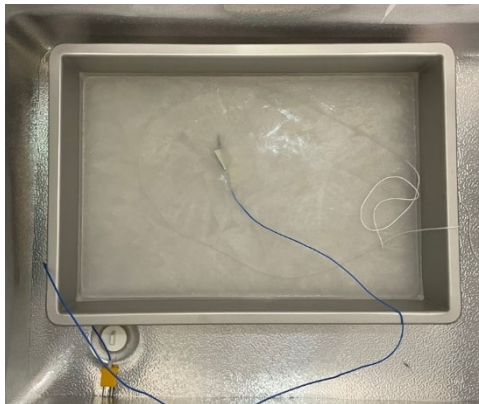


Figure 4. Freezing setup of the ice slab.

4. Place the first thermocouple into the water with the string such that the thermocouple is floating in the center of the water and the other end of the thermocouple is hanging out of the pan, as depicted in Figure 4. Allow this layer to freeze for ~ 24 hours.
5. Without disturbing the baking pan, pour another 488 mL of water over the first layer.
6. After another 24 hours, remove the ice slab from the freezer.
7. Tie the two strings to the crossbar with minimal slack in the string.

8. Remove the ice slab from the baking pan. A heat gun may be helpful to dislodge the ice slab from the baking pan, but try to minimize water loss during this step.
9. Place the graduated cylinder below the enclosure.
10. Slowly lower the ice slab into the enclosure. Rest the crossbar such that the ice is suspended above the pipes. Ensure that the ice slab is centered and is not in contact with the pipes.
11. Suspend the second thermocouple freely inside the enclosure to measure the ambient temperature.
12. Begin recording temperature of the ice slab and the air inside the enclosure.
13. The graduated cylinder used for this experiment had the lowest reading of 50 mL [8]. In the case of this experiment, it took 30 minutes to reach 50 mL. Thus, steady state was assumed at this point.
14. Record the amount of water in the graduated cylinder and the two temperature readings every 5 minutes over a one-hour period.

RESULTS AND DISCUSSION

The experiment was conducted three times, and the results were analyzed using the average of the three data sets. Figure 5 shows a plot of the average measured volume over 60 minutes.

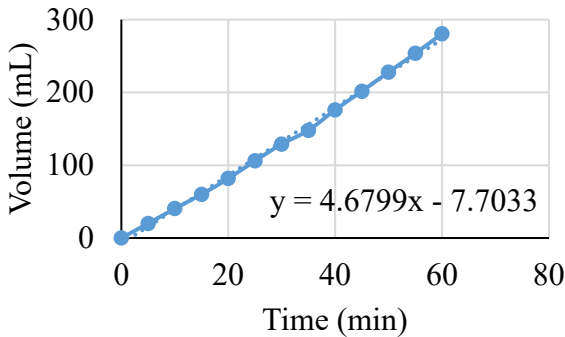


Figure 5. Average measured volume over 60 minutes.

The slope of the line in Figure 5 is the average measured volumetric flow rate of the three data sets in mL/min. In this case, one milliliter of water is equal to one gram of water. Thus, the average measured

volumetric flow rate can be expressed as an average measured mass flow rate in g/min. Converting this to grams per hour, the average measured mass flow rate was 280.79 g/hr. The measurements from each of the three data sets are provided in Table A1 of the Appendix. Note that the first data point in Figure 5 was taken 30 minutes after the ice slab was suspended in the apparatus to ensure steady state was reached. Also, after approximately one hour, the string was no longer in ice causing the ice slab to fall and terminating data collection.

The mass flow rate was also predicted using Eq. (11). The temperature of the surroundings (T_{∞}) was 19.29°C. This was determined by taking the average of the measured surrounding temperatures. The properties of air that were used were provided in Table A-15 from reference [1]. From Eq. (11), the predicted mass flow rate was 172.56 g/hr. Comparing the measured mass flow rate to the predicted mass flow rate there is a large 62.72% error between the two.

SOURCES OF ERROR

The first main source of error was with measuring the mass flow rate. A graduated cylinder was used to measure volume, and a phone timer was used for time. The 500-mL graduated cylinder used is rated to an accuracy of ± 5 mL [8]. Thus, the measurements would have some errors. Another error may be the time measurement. The measurements were taken every five minutes, although the five-minute mark may not have been exactly matched for every measurement.

The next main source of error was the formation of the ice slab. First, when measuring the water to be frozen, a large beaker was used. This has a high margin of error so using a more accurate instrument like a pipet or burette would increase accuracy. Also, a heat gun was used to dislodge the ice slab from the pan. This melted approximately 25 mL of water, which may have not been fully accounted for. Additionally, when freezing, if the water is not level, then the ice slab will form a nonuniform shape. This causes the ice slab to melt at different rates along its surface. Next, if the first half of the ice has not had sufficient time to freeze when the second layer is poured, the ice may crack, causing the second layer to freeze in an irregular shape. However, since the height and width of the ice slab are more pertinent to the experiment, the irregularities in thickness should not affect the results too much.

Finally, the experimental apparatus may have caused some errors. Specifically, the apparatus enclosed the ice slab in all directions. This may have prevented the air inside the enclosure from stabilizing with the environment. This could lead to higher temperatures inside the enclosure, leading to a higher mass flow rate. Next, adding a

thermocouple to the outside of the enclosure to measure its surrounding temperature would help verify the stable condition within the enclosure. Another source of error is radiation heat transfer from the surroundings. This can be reduced by running the experiment as far as possible from any walls. An additional source of error in the set-up may be water loss due to evaporation. Water that gets stuck on the ramp or that evaporates out of the graduated cylinder contributes to losses. These could be reduced with a more hydrophobic pipe. However, because the experiment is short and was performed in a cool environment, this would display a small difference. The last possible source of error may be air bubbles formed during the freezing process. It may have affected the melting rate of ice.

CONCLUSION AND RECOMMENDATIONS

The purpose of this experiment was to study natural convection by melting a slab of ice. The mass flow rate of the ice was measured and predicted. The measured mass flow rate was 280.79 g/hr, whereas the predicted mass flow rate was 172.56 g/hr. Overall, there was a large 62.72% difference between the measured and predicted mass flow rates, likely caused by numerous sources of error.

To improve upon this experiment, a constant temperature environment would allow for more stable conditions surrounding the ice slab. Additionally, the effects of radiation heat transfer should be considered.

ACKNOWLEDGMENTS

This project would not have been possible without the help and support of the Department of Engineering and Technology and the Department of Chemistry at Southern Utah University. Their contributions included providing the equipment and assistance from faculty. The undergraduate research was also partially funded by the NASA Utah Space Grant Consortia.

REFERENCES

- [1] Çengel YA and Ghajar AJ, *Heat and Mass Transfer: Fundamentals & Applications*. New York: McGraw-Hill Education, 2020.
- [2] Dizadji N and Entezar P, "Behavior of ice melting in natural convection," *International Journal of Chemical and Molecular Engineering*, vol. 6, no.1, pp. 97-100, 2012.

[3] Saidi M and Abardeh RH, “Air pressure dependence of natural-convection heat transfer,” *Proceedings of the World Congress on Engineering 2010 Vol II*. Hong Kong: Newswood Academic Publishing, 2010.

[4] Granger RA, *Experiments in Heat Transfer and Thermodynamics*, (Experiment 9, pp. 54-60). Cambridge, UK: Cambridge University Press, 1994.

APPENDIX

EXPERIMENTAL DATA

In this Appendix, all of the experimental data collected for the three trials are given in Table A1.

Table A1. Measured volume over 60 minutes for Trials 1, 2, and 3 with their respective average surrounding temperature (°C)			
	Trial 1	Trial 2	Trial 3
Temperature (°C)	18.9	20.0	19.0
Time (min)	Volume (mL)		
0	0	0	0
5	20	20	20
10	41	40	40
15	60	60	60
20	79	85	81
25	100	110	108
30	121	133	133
35	142	147	155
40	165	183	180
45	190	210	205
50	215	239	230
55	235	266	260
60	262	295	285

Make Haste Deliberately: The Historical American Aversion to Inoculations and Vaccinations with a Complicit CDC and FDA

Thomas C. Terry

Utah State University

Abstract

Joel Valdez languished 11 days in a Houston hospital, waiting for surgery after being shot six times during a robbery. The family of Ray DeMonia of Cullman, Alabama, reportedly contacted 43 hospitals in three states unsuccessfully searching for an open cardiac intensive care unit bed for him before he died. Three hospital groups in Salt Lake City, swamped with COVID-19, postponed “not immediately life-threatening surgeries,” causing William, 11, born with multiple heart defects, to have two surgeries cancelled in early November 2021. All fell victim to what the U.S. Centers for Disease Control and Prevention (CDC) director Rochelle Walensky called an “epidemic of the unvaccinated.” This is nothing new. In 1721, Rev. Cotton Mather, of Salem Witch Trials notoriety, supported the then-experimental inoculation procedure of variolation to combat a smallpox outbreak brought in Boston. A bomb was hurled through the window of his home at 3 a.m., failing to detonate, perhaps purposefully. Attached was a note: “Cotton Mather... I’ll inoculate you with this...” In 1776, Congress forbade physicians from

inoculating soldiers for smallpox. George Washington defied them, believing the Continental Army had “more to dread” from the disease “than the Sword of the Enemy,” and completing the successful and mandatory mass inoculation of his army in January 1777. In late 2020, government officials postponed vaccine Emergency Use Authorization decisions for the Thanksgiving holidays, ignoring the example of a Thanksgiving Day 76 years earlier when U.S. and allied soldiers, rather than pausing for a turkey feast, liberated the Natzweiler-Struthof Nazi death camp near Strasbourg, Germany. This article looks at vaccine hesitancy in American history, aided and abetted by politicians and confusing, contradictory, and sometimes deadly public health behavior by the CDC and U.S. Food and Drug Administration, including repeated reauthorization of the infamous Tuskegee Study of Untreated Syphilis of 399 poor Black men in Alabama from 1932 until 1969 and the denial that AIDS could be transmitted through blood transfusions.

Joel Valdez was shot six times on August 2, 2021, in Houston, Texas, a bystander to a domestic dispute.¹ Eleven days later on August 17, he was still awaiting surgery at Houston’s Ben Taub Hospital, which was swarmed by COVID-19 patients. A hospital representative blamed the delay on the coronavirus, stating, “Due to strained resources, surgical patients are being prioritized” and some operations were delayed, such as the one Valdez needed, which the hospital decided was one of the “nonemergent procedures.”² While Valdez languished in his hospital bed, police arrested the alleged gunman within a few days.³

A month later, Ray DeMonia, stricken by a heart emergency, died on September 1, 2021, three days short of his 74th birthday.⁴ His local hospital in Cullman, Alabama, reportedly could not find a free cardiac intensive care unit bed at 43 hospitals across three states amid a surge in

¹ Kim Bellware, “Man shot 6 times waits more than a week for surgery after hospital is overwhelmed by covid,” *Washington Post*, August 16, 2021, accessed October 25, 2021, at <https://www.washingtonpost.com/health/2021/08/16/joel-valdez-houston-covid-hospitals/>; and Bevan Hurley, “Man shot six times waits for more than a week for surgery because of covid,” *The Independent*, August 17, 2021, accessed October 25, 2021, at <https://www.the-independent.com/news/world/americas/crime/surgery-covid-icu-houston-b1904008.html>.

² *Ibid.*

³ *Ibid.*

⁴ Timothy Bella, “Alabama man dies after being turned away from 43 hospitals as covid packs ICUs, family says,” *Washington Post*, September 12, 2021, accessed October 25, 2021, at <https://www.washingtonpost.com/health/2021/09/12/alabama-ray-demonia-hospitals-icu/>.

COVID-19 cases in his home state. He was finally airlifted to a Mississippi hospital, but never recovered.

Three hospital groups in Salt Lake City, Utah, swamped with patients with coronavirus complications and hospitalizations, postponed what they deemed “not immediately life-threatening surgeries.”⁵ Eleven-year-old William, born with multiple heart defects, had two surgeries canceled in early November 2021 because Utah’s healthcare system was overwhelmed. The family tried nearby states, but their insurance would not necessarily cover out-of-network facilities, making an already horrible situation far, far worse.

Dale Weeks of Newton, Iowa, waited over two weeks to be transferred from his rural hospital to a larger one to treat his sepsis in the same month.⁶ However, Iowa healthcare facilities were inundated with unvaccinated COVID-19 patients, according to his family, and there were no beds available for 15 days. He finally had surgery, but his condition had degraded too far, and he died on November 28, 2021, age 78.⁷



Americans have a long history of opposition to public health advice and inoculation. The Rev. Cotton Mather (Figure 1), most famous for his defense of the Salem Witch Trials,⁸ supported the then-experimental inoculation procedure of variolation to combat a smallpox outbreak brought to Boston by a British warship in 1721.⁹ For Mather’s troubles, a bomb was hurled through the window of his home at 3 a.m. one morning, but it failed to detonate, perhaps intentionally as a warning. In words eerily familiar to modern ears, a threatening note was attached: “Cotton Mather, you dog, dam you! I’ll inoculate you with this; with a

⁵ Erin Alberty, “Exhausted by holes in his heart, this Utah boy must wait for surgery as COVID-19 adds to hospital overcrowding,” *Salt Lake Tribune*, November 7, 2021, accessed October 25, 2021, at <https://www.sltrib.com/news/2021/11/07/exhausted-by-holes-his/>.

⁶ Timothy Bella, “<https://www.washingtonpost.com/health/2021/12/28/iowa-dale-weeks-hospitals-covid-sepsis/>,” *Washington Post*, December 28, 2021, accessed January 3, 2022, at <https://www.washingtonpost.com/health/2021/12/28/iowa-dale-weeks-hospitals-covid-sepsis/>.

⁷ *Ibid.*

⁸ Cotton Mather, *Wonders of the Invisible World. Observations as Well Historical as Theological upon the Nature, the Number and the Operations of the Devil* (Boston, 1692).

⁹ Mark A. Best, Duncan Neuhauser, and Lee Slavin, “Benjamin Franklin: verification and validation of the scientific process in healthcare” (Victoria, BC, Canada: Trafford Publishing, 2003).

Pox to you.”¹⁰ Fifteen years earlier, Mather’s slave, Onesimus, described the inoculation process he underwent as a child in West Africa where it was common practice.¹¹



Figure 1. Rev. Cotton Mather (1663-1728). Mezzotint portrait by artist Peter Pelham, c. 1700. Columbia Law School.

In 1776, Congress, otherwise busy with declaring independence and mounting a revolution, forbade Army physicians from inoculating soldiers. Fortunately, George Washington defied them as well as the governors and laws of numerous states, believing the Continental Army had “more to dread” from smallpox “than the Sword of the Enemy.”¹² In one of his greatest tactical gambles and successes, Washington began the successful and mandatory mass inoculation of his army in January 1777.¹³

¹⁰ Mark A. Best, Duncan Neuhauser, and Lee Slavin, “‘Cotton Mather, you dog, dam you! I’ll inoculate you with this; with a pox to you’: smallpox inoculation, Boston, 1721,” *Quality and Safety in Healthcare*, 2004; 13(1): 13:82–83, 83.

¹¹ Ola E. Winslow, *A Destroying Angel: The Conquest of Smallpox in Colonial Boston* (Boston: Houghton Mifflin, 1974), 33. Onesimus told Mather that “he had undergone an Operation, which had given him something of ye Small-Pox, and would forever preserve him ... from ye Fear of the Contagion” if someone had the “Courage to use it.”

¹² Letter from George Washington to William Shippen, Jr., February 6, 1777, from Washington’s headquarters at Morristown, New Jersey.

¹³ Ann M. Becker, “Smallpox in Washington’s Army: strategic implications of the disease during the American Revolutionary War,” *Journal of Military History*, 2004; 68(2): 381-430, 389. A direct ancestor of the author was one of the soldiers inoculated.

Put aside the political tempest generated by face masks and the vaccine and Americans' historical aversion to inoculations for the moment and look at the history of recommendations and general behavior by the U.S. Centers for Disease Control and Prevention (CDC). COVID-19 became "the pandemic of the unvaccinated" in the words of CDC director Dr. Rochelle Walensky, adding that 99% of those who died in January–July, 2021, were unvaccinated.¹⁴ Yet, when Pfizer announced on April 15, 2021, that data argued for a booster, the CDC lambasted it as premature. After months of waffling by top epidemiologists and government healthcare officials and without any apparent embarrassment or sense of irony, the CDC recanted and recommended third shots to top off immunity. By that time, however, as many as one million Americans had studied the same data as the CDC and, correctly it seems, pursued a third jab on their own initiative.

The advice of public health officials over the course of the pandemic has been confusing, and citizens have had to puzzle out dueling advice for themselves: "do not use masks" and then "use masks"; "you only need to wash your hands"; "do not mix hand sanitizer at home" even though the CDC offered a formula on its website to do exactly that; "six-feet separation is enough," even though a sneeze travels two or three times that distance; "quarantine for 10 days" and then "five days"; and on and on. "Follow the science" was the pandemic mantra from physicians and public health experts, something that in the past has included employing leeches and bloodletting to cure various ailments, collapsing lungs to combat tuberculosis, giving smoke enemas to resolve many conditions, and prescribing radium as an analgesic. Certainly, those barbaric remedies are relegated to an ignorant past. Except that the efficacy of bypass surgery and implantation of stents is at the very least controversial, yet nearly a million procedures are performed annually.¹⁵

Similarly, in the midst of the AIDS crisis in the 1980s, Dr. Joseph Bove, the chair of the U.S. Food and Drug Administration (FDA)'s Blood Products Advisory Committee, announced that transmission of AIDS through blood transfusions was impossible.¹⁶ The FDA approved

¹⁴ Sarah Betancourt, "It's too late:" US doctor says dying patients begging for Covid vaccine," *The Guardian*, July 22, 2021, accessed October 25, 2021, at <https://www.theguardian.com/us-news/2021/jul/22/us-coronavirus-covid-unvaccinated-hospital-rates-vaccines>.

¹⁵ Tracie White, "Stents, bypass surgery show no benefit in heart disease mortality rates among stable patients," *Stanford Medicine News Center*, November 16, 2019, accessed October 25, 2021, at <https://med.stanford.edu/news/all-news/2019/11/invasive-heart-treatments-not-always-needed.html>.

¹⁶ Lisa Russell, "The inadequate response of the FDA to the crisis of AIDS in the blood supply," third-year paper, Harvard University, 1995:1-46. Accessed October 25, 2021, at <http://nrs.harvard.edu/urn-3:HUL.InstRepos:8965576>. Bove was also director of the blood

Biogen's Aduhelm (aducanumab) for the treatment of Alzheimer disease in June 2021, prompting the resignation of three advisory committee members¹⁷ and the refusal by the Cleveland Clinic, Mount Sinai Health System in New York, and Providence in Renton, Washington, to administer the drug.¹⁸ Perhaps oddly, in Utah, Idaho, and Wyoming, among other states, opponents of vaccination ignored the scientific evidence they could witness themselves, while simultaneously accepting the science that the state and the West were experiencing a drought, something they could also see. About 20 countries, including Canada, Britain, Germany, and the European Union as a whole, in response to emerging research, suggested that mixing one of the two mRNA vaccines with the AstraZeneca vaccine could boost its effectiveness.¹⁹ That particular science was ignored as well.

This sample of conflicting and inaccurate or underdeveloped advice does not even address the understandable suspicions of communities of color victimized by the CDC and its predecessors. The most infamous case was the Tuskegee Study of Untreated Syphilis involving approximately 400 Black men—poor sharecroppers in Alabama—from 1932 until 1969, which was routinely and repeatedly reauthorized by the CDC.²⁰ It took an Associated Press exposé in 1972 on the front page of the *New York Times* to bring about the cancellation of the study. Reporter Jean Heller detailed Public Health Services investigator Peter Buxton's revelations that the CDC had not properly informed participants of the risks when they were originally recruited and never told them of the effective medications against the venereal disease for nearly three decades before the study was scrubbed. Of the original

bank at Yale University Medical Center and an officer of the American Association of Blood Banks.

¹⁷ Bill Chappell, "3 experts have resigned from an FDA Committee over Alzheimer's drug approval," NPR, June 11, 2021, accessed October 25, 2021, at <https://www.npr.org/2021/06/11/1005567149/3-experts-have-resigned-from-an-fda-committee-over-alzheimers-drug-approval>.

¹⁸ Joseph Walker, "Cleveland Clinic, Mount Sinai and Providence won't give Biogen's new Alzheimer's drug," *Wall Street Journal*, July 15, 2021, accessed October 25, 2021, at <https://www.wsj.com/articles/cleveland-clinic-mount-sinai-wont-give-biogens-new-alzheimers-drug-11626366968>.

¹⁹ Dyani Lewis, "Mix-and-match COVID vaccines: the case is growing, but questions remain," *Nature* 2021; 595(7867): 344-345.

²⁰ The CDC was originally the singular Center for Disease Control. The name was changed in late 1992 to Centers for Disease Control and Prevention without the necessity of changing the acronym.

399 men in the study group, 28 had died of syphilis directly and another 100 of related complications by the time it was cancelled. Forty of their wives contracted syphilis, and 19 of their children were born with congenital syphilis.²¹ Little wonder that Americans quite reasonably pause cynically as the latest sound bite advocates some new medical advice or alters—even contradicts—previous recommendations.

During the COVID-19 pandemic, top public health officials changed their minds and recommendations so often it was hard to keep track of who said what when before revising it again and again and whenever. Science, it seems, is a movable feast and sometimes dubious target. Add into all this the chaos and scale of coordinating the governors or political leaders of 50 states, the District of Columbia, Puerto Rico, numerous other territories, and thousands of local health departments, topped up by unfathomably daunting and invariably disorganized medical and governmental bureaucracies. The government response resembled the pandemonium at the Kabul airport as the U.S. precipitously extricated itself from Afghanistan—with the notable exception of Operation Warp Speed, which rapidly brought highly effective vaccines to tens of millions of Americans.

Conflicting and confusing advice was announced with almost religious certainty at almost every stage of the pandemic by the White House, the FDA, and the CDC, complicating—contaminating may not be too strong a word—the process, and leaving Americans perplexed, sullen, and suspicious. The face mask remains the perfect foil and emblem—the modern Scarlet Letter in some circles—for the entire range of coronavirus rules and recommendations. The quasi-deifications of Dr. Anthony Fauci and Gov. Andrew Cuomo and the simultaneous demonization (or veneration, depending on your politics) of President Donald Trump overshadowed and/or corrupted every aspect of governmental responses to the pandemic.

Six days before Thanksgiving 2020, Pfizer-BioNTech and Moderna submitted data on their COVID-19 vaccines to the FDA seeking Emergency Use Authorization (EUA). The CDC Advisory Committee on Immunization Practices (ACIP) met three days later—three days *before* Thanksgiving—but did not recommend the EUA. Its

²¹ James H. Jones, *Bad Blood: The Tuskegee Syphilis Experiment* (New York: The Free Press, 1982); and Jean Heller, “Syphilis victims in U.S. study went untreated for 40 years,” *New York Times*, July 26, 1972, 1, 8.

next meeting—a non-emergency one—was not scheduled until the Tuesday *after* Thanksgiving...when committee members would consider an *emergency* vaccine decision. And it was not until December 10, exactly two weeks *after* Thanksgiving, that the ACIP voted to recommend that the Pfizer-BioNTech vaccine receive an EUA, the same day as the FDA’s Vaccines and Related Biological Products Advisory Committee, a committee that had not met since October, came to the same conclusion at a separate meeting, A day after that, on December 11, 2020, the FDA took the advice of both advisory panels and approved the EUA for the Pfizer-BioNTech vaccine for those 16 years and older.

On December 18, 2020, the FDA issued an EUA for the Moderna COVID-19 vaccine for those 18 years and older after both advisory panels recommended it. FDA commissioner Dr. Stephen M. Hahn had previously promised to review the request “expeditiously” in a “thorough and science-based manner,” so that Americans could have a vaccine they “deserve as soon as possible,” although the deliberate pace of discussions belied that pledge.²²

On June 28, 2022, the Vaccines and Related Biological Products Advisory Committee of the FDA met to consider the wisdom and necessity of a reformulated COVID-19 shot and overwhelmingly endorsed it. It took over two months more for the FDA on August 31 and the CDC (and its director) on September 1 to approve a revision to the EUAs allowing the new vaccine. And despite that lengthy delay—which included time-off for the July 4 holiday—no human trials were completed to obtain more data on the safety or efficacy of the new jabs.

Even when the COVID-19 vaccines were approved, last-minute orders, delivery lags, transportation bedlam, and the panic and desperation of the population put health officials far behind the curve. Additionally, the short supply of vaccines in the midst of a surge of cases created numerous dilemmas: Should the limited inventory be used to fully vaccinate high-risk populations, including healthcare providers, with two or three doses or to give more people a first dose? And how to define high-risk and classify priority populations?

²² “Coronavirus (COVID-19) update: FDA announces advisory committee meeting to discuss COVID-19 vaccine candidate,” U.S. Food and Drug Administration, news release, November 20, 2020, accessed October 25, 2021, at <https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-announces-advisory-committee-meeting-discuss-covid-19-vaccine>.

Conversely, Africa had a shortage of vaccine doses and waited for dosages already ordered, including tens of millions in South Africa alone. Yet at the same time, Johnson & Johnson vaccines manufactured in South Africa were being exported to Europe.²³ As demand rose and fell along with case numbers, the equitable worldwide distribution of the vaccine supply that the World Health Organization (WHO) demanded was pathetically slow and unpredictable.

Stretching the interval of vaccination became another option that was ignored, a strategy that would have thrown literal lifelines to developing nations and prove the wisdom of extinguishing a fire before it reaches your house as other mutations evolved in those nations without preventative mass inoculation. The WHO recommended such alternatives to increase general coverage in regions with greater transmission and insufficient supply. Wealthy nations were unwilling to suffer the domestic price, perhaps understandably, in lives and political fall-out that would have occurred.

The U.S. and other affluent and (relatively) high-coverage nations engaged in heated discussions about vaccine hesitancy, vaccination mandates, and vaccine passports while the developing world especially was ravaged by the virus with appallingly little supply of vaccines to battle it. In the U.S., individuals of all ages except the very young eventually became eligible for a vaccine, compounding the international supply chain dilemma, although the number of Americans who have received more than two shots is comparatively low. And there is insufficient media attention in wealthy nations and inadequate tracking of the disease in poorer countries to provide a truly accurate picture of the scale of the pandemic. Rich nations abrogated their moral responsibilities by piling on vaccine boosters while other nations coped without any shots as the smoke from funeral pyres, such as those in India, rose higher into the sky.

Nations across Africa, the Indian subcontinent, parts of North America (Mexico), and China simply lied—and continue to lie—about their number of deaths. Not every country was as privileged as the U.S. with ample supply to offer bribes—charitably called “incentives”—from lottery tickets to beer to guns to encourage resisting or procrastinating

²³ Rebecca Robbins and Benjamin Mueller, “Covid vaccines produced in Africa are being exported to Europe,” *New York Times*, August 16, 2021, accessed October 25, 2021, at <https://www.nytimes.com/2021/08/16/business/johnson-johnson-vaccine-africa-exported-europe.html>.

individuals to get vaccinated.²⁴ Airlines, businesses, sports leagues, Hollywood, and government entities mandated vaccinations, stirring up controversy—and violence—at school board meetings and on commercial flights. “Brandon” and “Karen” used to be the names of your high school classmates. The internet is awash with lies and fear and false information, fueled by politicians eager to snare a few more votes on the electoral battlefields, a situation made worse by the ponderous FDA/CDC bureaucracy and the clash of competing advice. Herd immunity is inevitable through vaccination or disease; the only question involves the eventual body count.

And things *could* still get ghoulishly worse if a variant impervious to vaccines appears. In the midst of the Spanish Flu pandemic, officials in Washington, D.C., empowered by a Board of Health edict, confiscated two train loads of coffins heading to Pittsburgh, to instead bury the capital city’s dead.²⁵ Do not look to the U.S. Supreme Court for relief. The Justices shied away from entering the COVID-19 fray—despite its eagerness to enter the battleground over other healthcare issues, such as abortion—refusing to hear legal challenges to vaccine mandates in Maine and New York City and at Indiana University, among many others. But this is the very American thing to do, after all, at least if history is any guide.



War is often used as a metaphor for the fight against disease. More than three times as many Americans have died from COVID-19—and continue to die—than U.S. soldiers were killed during World War II. On Thanksgiving Day 1944, 76 years before Thanksgiving 2020 when everyone involved in vaccine decision-making was observing the holiday, soldiers of the American 6th Army Group in tandem with French forces liberated the Natzweiler-Struthof Nazi death camp,²⁶ about 31 miles southwest of Strasbourg, Germany (Figure 2).

²⁴ Kate Gibson, “West Virginia’s COVID-19 vaccine incentives include guns, trucks and cash,” CBS News, June 2, 2021, accessed October 25, 2021, at <https://www.cbsnews.com/news/west-virginia-vaccine-lottery-guns-trucks-cash/>.

²⁵ Christopher Klein, “How America struggled to bury the dead during the 1918 Flu Pandemic,” History.com, February 12, 2020, accessed October 25, 2021, at <https://www.history.com/news/spanish-flu-pandemic-dead>.

²⁶ Approximately 22,000 people were murdered by gas at the Nazi Natzweiler-Struthof extermination camp. The victims were mostly Jews and members of the French Resistance.



Figure 2. Natzweiler-Struthof Death Camp. Nov. 30, 1944, seven days after its liberation. Photo by Braze J. McCroby, U.S. Army. *United States Holocaust Memorial Museum*

They did so rather than pause for turkey and dressing and general Thanksgiving festivities and instead made an emergency authorization decision of a different sort that undoubtedly saved lives. In the future, perhaps the CDC and the FDA and their various advisory committees could adopt the motto of the Emperor Augustus: “Festina Lente” (Make Haste Deliberately) and do so “Sine Mora” (Without Delay) by scheduling emergency meetings to combat public health crises without regard for holidays or weekends or summer vacations.

Collisional Losses in a Variable Specific-Impulse Magnetoplasma Rocket

Benjamin Miera and Philip Matheson
Utah Valley University

Abstract

A variable specific-impulse magnetoplasma rocket (VASIMR) is a potential means of powering future deep space missions. The engine uses radiofrequency (RF) energy to first ionize argon with a helicon antenna and to subsequently heat the resulting plasma through ion cyclotron heating (ICH) which then creates thrust in a magnetic nozzle. Our previous studies have modeled the increased specific impulse and thrust generated in a collisionless plasma. This work includes ion-neutral collisions in the simulation, which reduces the number of ions in the plasma stream and thus reduces thrust. This study analyzes the loss of thruster efficiency caused by such collisions in the nozzle region of the VASIMR. The plasma is considered weakly ionized, and other plasma effects, such as ion-ion and ion-electron collisions, are ignored. Monte-Carlo methods are used to determine ion losses from a stream of individual argon ions as they move along the engine. Neutral densities are inferred from stipulated mass flow rates and ionization fractions. These are functions of the initial ionization process involving a helicon antenna, whose properties are inferred from this study, but not directly dealt with. Ion temperatures, and hence velocities, are determined as

products of the ICH process. Efficiency of the engine varies widely with initial mass flow rates and the subsequent neutral backgrounds these produce, but in this simple study, collisional losses are large, for even moderate neutral backgrounds. An effective VASIMR thus requires an extremely efficient initial ionization mechanism.

Background

A VASIMR (variable specific-impulse magnetoplasma rocket) thruster is an electrically powered engine that uses plasma as a propellant [1]. The VASIMR engine is designed to provide higher specific impulse and greater thrust efficiency compared with traditional chemical rockets.

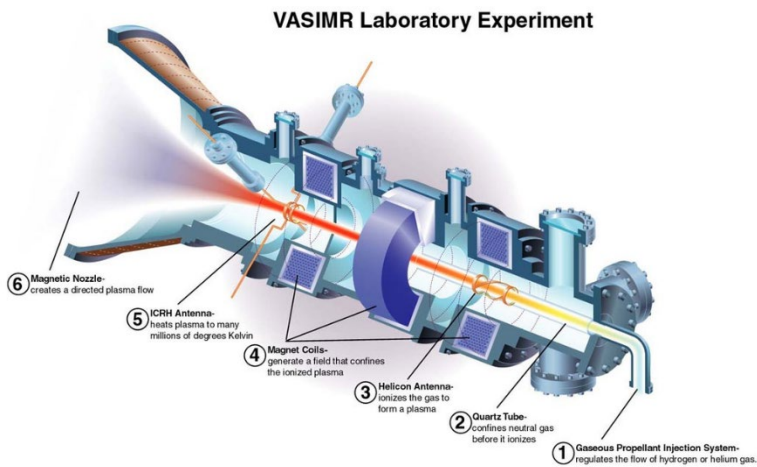


Figure 1. Diagram showing the operation of a VASIMR (variable specific-impulse magnetoplasma rocket). NASA, Public Domain, via Wikimedia Commons.

An experimental prototype version of the engine, the VX-200, has been undergoing development and testing for many years by the Ad Astra Rocket Company [2, 3]. We consider this device to establish the base marks for comparison studies. The engine works by ionizing a gas, such as hydrogen, helium, or, in our simulation, argon, using a helicon antenna [4] (circle 3 in Figure 1). An axial magnetic field keeps the plasma traveling along the axis of the engine (circle 4 in Figure 1). The ions gyrate with frequency $\omega_L = \frac{qB}{m}$, where q is the ion charge, B the magnitude of the magnetic field, and m is the mass of the ion. In the

absence of accelerating electric fields, the magnetic moment of the ion, $\mu = 1/2 \frac{mv_{\perp}^2}{B}$, and the total kinetic energy, $E = \frac{1}{2}mv_{\parallel}^2 + \frac{1}{2}mv_{\perp}^2 = \frac{1}{2}mv_{\parallel}^2 + \mu B$, are constants of the motion. Consequently, the axial velocity of the ions, v_{\parallel} , increases as the magnetic field, B , decreases in the expansion region of the magnetic nozzle (circle 6 in Figure 1). This is the source of thrust. The key element to the VASIMR is in using a circularly polarized electric field that rotates in synchrony with the ion gyrofrequency ω_L , increasing v_{\perp} and, hence, the magnetic moment of the ion. This is ICH heating indicated by circle 5 in Figure 1. The energy injected into the ions in this manner is then converted to thrust in the nozzle region as the pumped component of the ion velocity, v_{\perp} , is converted to increased axial v_{\parallel} . Exit velocities as high as 50 km/s are possible, or reckoned in terms of specific impulse, $I_{sp} = 5000$ s, which is more than an order of magnitude larger than those possible from chemical rockets [5]. At such high values of specific impulse, the thrust generated is necessarily small, but just as with electric ion engines, it can be maintained over long times. An additional advantage to the VASIMR engine over an electric ion thruster is that the specific impulse and thrust parameters can be varied from relatively high thrust and low specific impulse (such as might be used in exiting a planetary gravity well) to low thrust and high specific impulse (such as might be used in the interplanetary phase of a mission). There remain, however, substantial obstacles to the practical deployment of a VASIMR, such as the development of reliable, large-scale power supplies for long-term space use [6].

In previous studies [7], we have examined the efficiency of ICH heating by following individual ions as they pass through a simple computational model of a circularly polarized, rotating E-field. That study confirmed the results of other fluid-based plasma studies that high specific-impulse values are possible even with relatively small ICH heating regions. Those studies were “collisionless” in that the ions were simply integrated along their single particle trajectories and the resultant plasma properties were inferred by statistically averaging the properties of those individual ions. The same model is used here but is modified to eliminate some fraction of the ion population through simulation collisions with a neutral background.

The basic elements of the engine are modeled by a cylindrical tube having two current loops at either end that represent the confining magnets and a small ICH region just outside the exit loop (on the right in Figure 2). Our choice of model does not reflect the more uniform axial field produced by superconducting solenoids in the experimental VASIMR engines currently under study, but this model is accessible to

simple computational resources and is appropriate for heuristic discussion of plasma phenomena at an undergraduate level. The plasma is assumed to be initiated using a helicon antenna. However, these devices have a wide range of operating conditions and effectiveness [4,8], so that we characterize this source only by specifying an initial flow rate, ionization energy, and ionization fraction of the injected gas.

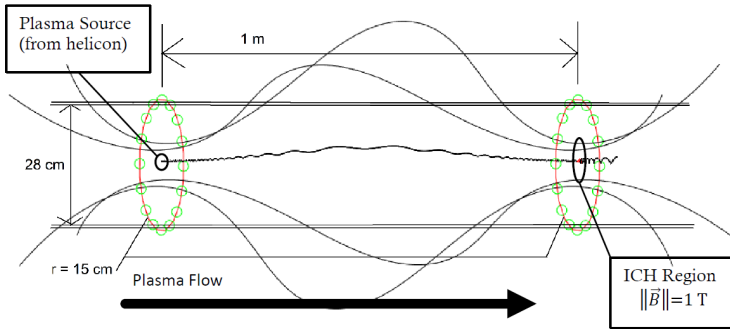


Figure 2. Diagram of the simulation setup and parameters. Red rings are current loops acting as superconducting magnets, approximated as regular polygons with corners marked by green circles. Four magnetic field lines are shown in black curves. The simulated path of one ion through the engine is shown. The black double-lines are the walls of the engine.

A thermal distribution of argon ions is generated at the entrance (left side of Figure 2), and the Lorentz force law, $m \vec{a} = q(\vec{v} \times \vec{B})$, is used to integrate the path of each ion through the engine. A Gaussian distribution of ions with a mean thermal speed of $v_0 = 1.7 \text{ km/s}$ is used as the source of particles. Only those ions in the narrow axial region along the center (that do not hit the wall) are used for subsequent analysis.

The ICH region is shown enlarged in Figure 3. During ICH, an electric field rotates in resonance with the ions in cyclotron motion. This has the effect of increasing in the ions' perpendicular velocity, which in turn increases their gyration radius, as seen in Figure 3. The ICH region is taken to be 1 cm in length, normal to the z axis with an electric field of uniform magnitude that abruptly falls to zero outside of that region. In reality, the ICH region would not be so simple, and the boundary between the inside and outside of the ICH region would not be so sharply

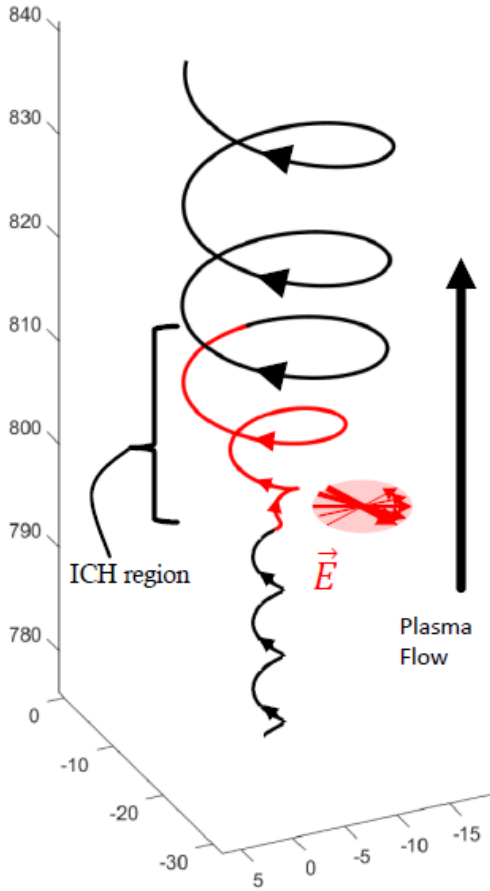


Figure 3. A zoomed-in view of the ICH (ion cyclotron heating) region shown in Figure 2, oriented so the engine nozzle is above. The magnetic field is aligned with the vertical axis, pointing upward. The electric field is rotating about the vertical axis. The ion's path is shown in red while inside the ICH region. The increase in the ion's magnetic moment is manifest in the increasing gyroradius of the ion, which shows an acceleration of the velocity in the direction perpendicular to the magnetic field. As the ion continues into regions of weakening magnetic field, the kinetic energy associated with this motion will be converted into kinetic energy parallel to the axis of the engine, thus producing enhanced thrust. Note that one distance unit along any of the three axes is approximately 0.628 mm.

delineated; however this simple model serves our purpose of investigating the basic physics of ICH heating. Figure 4 shows the nominal change in the distribution of the asymptotic values of the axial ion velocity for a collisionless plasma. The increased asymptotic axial velocity is a direct indicator of increased specific impulse of the propellant.

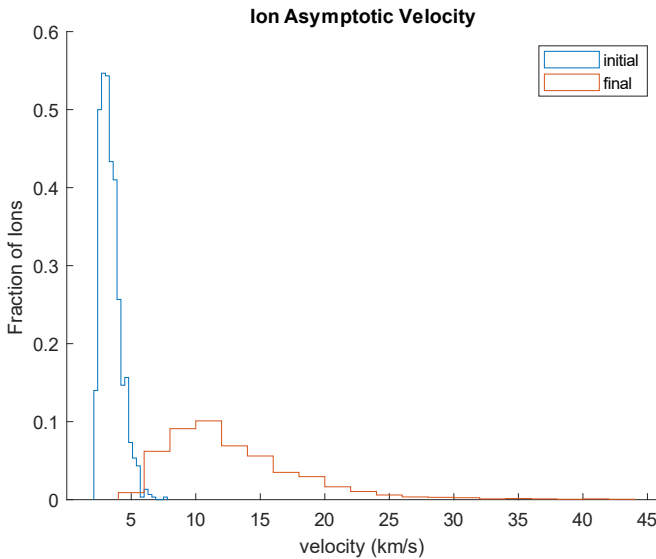


Figure 4. Ion velocity increase without accounting for collisions (equivalent to initial ionization fraction = 100%)

Using these simulation parameters, estimates of the upper limit of the engine's thrust and specific impulse were obtained for a variety of assumed mass flow rates and initial ionization fractions. Both of these parameters are contingent upon the physics of the helicon antenna, whose performance is then inferred from these results. A study of the Ad Astra VASIMR rocket [3] indicates that a mass flow rate of 120 mg/sec may be a nominal operating point for the engine during a planetary mission, and so we have based our study on this value.

MHD models or more sophisticated kinetic models of plasma flow in a VASIMR must deal with transport issues of collisional and diffusive loss. In our simple single particle model, we can approach these effects using Monte-Carlo methods with various transport and collision processes to modify individual particle behaviors. In this case, we

assume the major loss to the plasma will be through ion-neutral collisions and neglect all other forms of plasma interactions. For a plasma with neutrals much colder than ions, as they would be in the ICH region, the collision frequency is given by

$$f = n_0 \sigma_{\alpha|0} v_{\alpha,therm} \quad (1)$$

Here, f is the collisional frequency, n_0 is the neutral density, $\sigma_{\alpha|0}$ is the cross-section of an ion-neutral collision, taken as $5 \times 10^{-19} \text{ m}^2$, and $v_{\alpha,therm}$ is the ion thermal velocity,

$$v_{\alpha,therm} = \sqrt{k_B T_\alpha / m_\alpha}, \quad (2)$$

where k_B is Boltzmann's constant, T_α is the ion temperature, and m_α is the ion mass. If each simulation time step has duration of Δt , in the limit $\Delta t \ll 1/f$, then the probability of collision, p , within the time step is

$$p = f \Delta t \ll 1. \quad (3)$$

Then $1-p$ is the probability of not experiencing a collision. Using a simple random number generator, we compare $(1-p)$ to the "roll of the dice," and if the random number exceeds $(1-p)$, the ion is assumed to be lost from the distribution; otherwise, it is retained.

The efficiency of the engine is thus modified by the direct fractional loss of ions from the propellant stream.

The ion temperature, $T_\alpha(z)$, is calculated at each point along the z -axis by averaging over the velocity distribution of the ions. The neutral density is taken to be constant inside the engine, and is calculated as

$$n_0 = (1 - x) \frac{\rho}{\pi R^2 v_z}, \quad (4)$$

the mass-flow rate ρ divided by the volume flow rate (cross-sectional area of the engine πR^2 times the z -velocity of the neutrals v_z), times the initial neutral fraction (one minus the initial ionization fraction x). Outside the nozzle of the engine, the neutral density, $n(z)$, is taken to fall off exponentially with distance z from the nozzle as

$$n(z) = n_0 e^{-\frac{z}{2R}}. \quad (5)$$

In all, 2376 different engine configurations were examined using mass flow rates ρ from 10 to 240 mg/sec in increments of 10 mg/sec and initial ionization fractions x from 0.01 to 0.99 in increments of 0.01

Results

Without accounting for collisions or other many-particle interactions within the engine, we observed an operating specific

impulse of approximately 1300 seconds and a thrust of 1.6 newtons, with a thruster jet power of 10 kW at a mass flow rate of 120 mg/s. Despite minimal assumptions, these parameters are consistent with observed operating parameters of the VASIMR prototype VX-200 [3] (Figure 5).

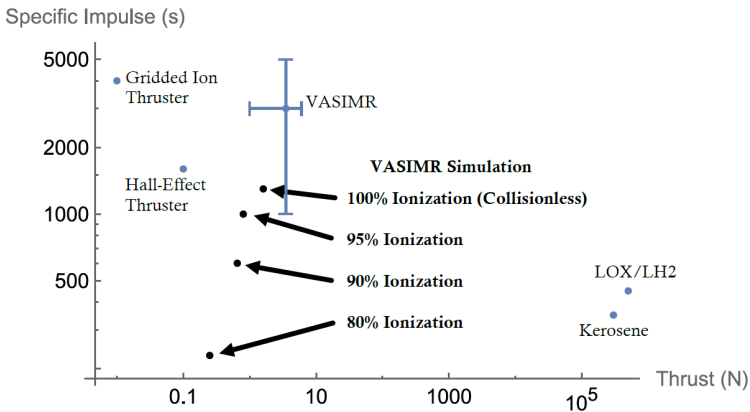


Figure 5. Specific impulse versus thrust for a few types of rocket and propellants. The measured VASIMR operating parameters [3] are shown, along with examples of our simulated results.

The ICH process in our model was observed to produce heating from 30,000 K to 500,000 K.

Figure 4 shows the change in the velocity distribution of the ions after passing through the engine. The nominal operating points given in Figure 4 are compared with VASIMR operating parameters given by Ad Astra [3] in Figure 5 by displaying the specific impulse achieved as a function of thrust produced. In short, the results displayed show that the initial ionization fraction of the plasma in the helicon must be near 100% to achieve reasonable performance.

In this study, we account for collision effects in the form of ion-neutral collisions. Collisions of any sort would tend to reduce the performance of the engine, and ion-neutral collisions are assumed to be the greatest contributor to performance loss. We naively assume that in any collision between an ion and a neutral atom, the ion is lost to the thrust stream.

To model these effects, we generated batches of ions in sets of 1000 ions and used Monte-Carlo methods to discard ions that experienced a collision. We simulated 2376 different combinations of the engine's mass flow rate and initial ionization fraction values to gain some insight

into the limiting effects of ion-neutral collisions. The resulting engine operating parameters are shown below in Figures 6 and 7.

Figure 6 covers the parameter space giving the ionized fraction of matter in the exit plume as determined from the input mass flow rate to the engine and the initial ionization rate in the helicon. Our crude model shows strong losses under nearly all circumstances. For instance, at a mass flow rate of 120 mg/sec with an initial ionization fraction of 80 percent (0.8), only 20% (0.2 contour line) survive as ions to contribute thrust to the engine. With an initial ionization fraction of 90%, the surviving fraction increases to 50%; even at 98% initial ionization, the mass fraction in ions in the thrust column only approaches 80%.

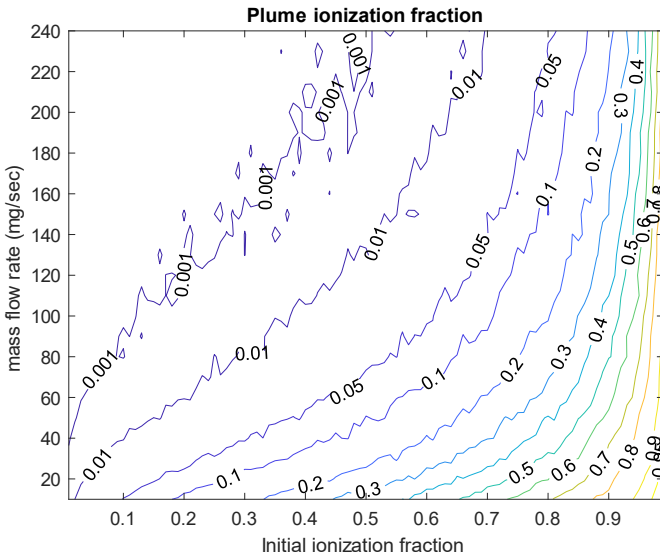


Figure 6. Plume ionization fraction versus mass flow rate and initial ionization fraction. Only a low initial neutral density leads to a large ionization fraction in the plume.

Figure 7 displays contours of constant thrust derived in the same parameter space. In a nominal collisional simulation, a mass flow rate of 120 mg of ions per second would develop roughly 1 N of thrust. With strong collisional losses, a feed rate of 120 mg/sec of argon with an initial ionization fraction of 80% reduces the generated thrust to 200 mN. The significant point again is that, unless the initial ionization fraction is in the high 90% range, ion-neutral collisions as modeled here can easily deplete the plasma column.

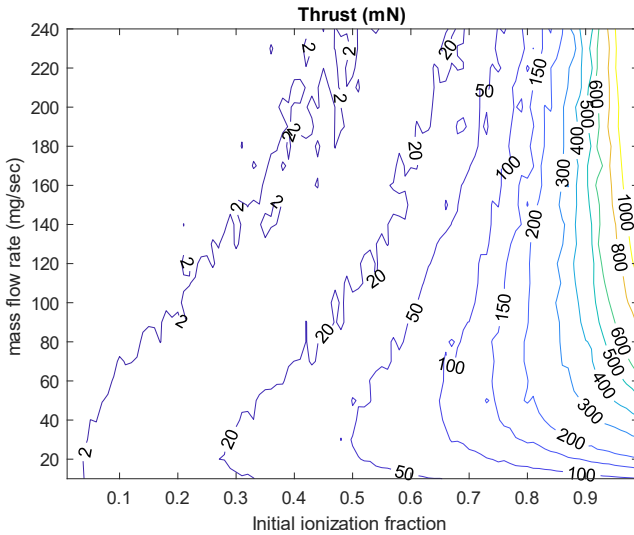


Figure 7. Thrust calculated from plume ionization fraction versus initial ionization fraction and mass flow rate.

Conclusion

It is apparent that collisional losses due to ion-neutral collisions in this model are overwhelming, except at high initial ionization fractions and low mass flow rates. Our model is simplistic. In addition to assuming a constant neutral density along the length of the engine, we assume that any ion-neutral collision results in the loss of that ion from the plasma stream. We neglect all other plasmas processes, including further ionization processes that may mitigate some of the losses discussed here. Other kinetic properties would act to remove the anisotropies in v_{\perp} and v_{\parallel} . These would also tend to reduce the thrust efficiency. Nevertheless, Ad Astra's most recent results with VX-200SS [9] developed thrust with such high efficiencies that if subject to the constraints of our simple model it is implied that the helicon ionization antenna must develop an initial ionization fraction on the order of 95% or more.

The intent of this study is to illustrate that simple, single-particle codes using elementary physics may be used to check or highlight results obtained with more elaborate fluid and kinetic codes. Some obvious extensions and improvements to our approach would be to also include other effects such as further ionization, explicit charge exchange and re-energization of these particles, and other kinetic processes.

References

- [1] Chang-Diaz, F.R. "The VASIMR rocket." *Sci. Am.* Vol. 283, No. 5, 2000, pp. 90-97. DOI: 10.1038/scientificamerican1100-90
- [2] Squire, J.P., Carter, M.D., Chang-Diaz, F.R., et al. "Development toward a spaceflight capable VASIMR® engine and SEP applications." AIAA Space and Astronautics Forum and Exposition (SPACE 2014) AIAA 2014-4173, 4-7 August 2014, San Diego, California. DOI: 10.2514/6.2014-4173
- [3] Longmier, B.W., Squire, J.P., Olsen, C.S., et al. "Improved Efficiency and Throttling Range of the VX-200 Magnetoplasma Thruster." *J Propul. Power.* Vol. 30, No. 1, 2014, pp. 123-132. DOI: 10.2514/1.B34801
- [4] Miljak, D.G., Chen, F.F. "Helicon wave excitation with rotating antenna fields." *Plasma Sources Sci. Technol.* Vol. 7, No. 1, 1998, pp. 61-74. DOI: 10.1088/0963-0252/7/1/009
- [5] Bering, E.A., Chang-Diaz, F.R., Squire, J.P. et al. "Electromagnetic ion cyclotron resonance heating in the VASIMR." *Adv. Space Res.* Vol. 42, No. 1, 2008, 192-205. DOI: 10.1016/j.asr.2007.09.034
- [6] Giambusso, M., Squire, J.P., Chang-Diaz, F.R., et al. "120 kW RF Power Processing Unit In-vacuum Testing for a VASIMR System." ASCEND 2020, AIAA 2020-4020, 16-18 November 2020 (Virtual event). DOI: 10.2514/6.2020-4020.
- [7] Miera, B., Matheson, P. Simulating ICH on ions in a VASIMR." Four Corners Regional Meeting of the American Physics Society, Oct. 2022, Albuquerque NM.
- [8] Del Valle, J.I., Granados, V.H., Chang, F.R. "Estimation of erosion phenomena within helicon plasma sources through a steady-state explicit analytical model." *Front. Physics.* Vol. 10, August 11, 2022, DOI 10.3389/fphy.2022.950472.
- [9] Chang-Diaz, F.R., Giambusso, M., Corrigan, A.M.H., et al. "Recent Progress on the VASIMR® Engine, IEPC-2022-525." Presented at the 37th International Electric Propulsion Conference, Massachusetts Institute of Technology, Cambridge, MA, June 19-23, 2022.

Question Answering on Quantum Computers

Thomas Draper

Brigham Young University

Abstract

The first quantum algorithm for processing language was run in 2020, sparking great research interest in the field. This article introduces the background of quantum computation as well as the relationship between quantum theory and the theory of natural language, intending to make the topic accessible to an audience familiar with linear algebra. No knowledge of linguistics or quantum computing is assumed. This paper illustrates the method of converting sentences to quantum circuits. The algorithm is implemented in Python to parse sentences and convert them to parameterized quantum circuits. IBM's Qiskit framework is used to build these circuits and evaluate them using simulators and actual quantum hardware. The circuit's parameters are optimized using a gradient-free machine learning method, which allows accurate predictions for the truth of simple sentences.

1. Introduction

Natural language processing (NLP) is all about using computers to process natural human languages, such as English. This is part of the intersection of linguistics and computer science and is also a major topic

in artificial intelligence (AI). There are some basic tasks, like grammatical parsing, that are relatively easy, but the NLP field also contains what are considered to be some of the hardest problems in AI. Tasks that require understanding the full meaning of a complex text (such as translation from one language to another) are considered “AI-complete”; this means that if you can make an algorithm to (for example) reliably translate between languages, then you probably can solve just about any AI-related problem, such as object recognition in video or even generalizing knowledge to tackle problems never before encountered by computers.

Neural networks (algorithms imitating the structure of a brain) are being used to solve NLP tasks with rapidly increasing accuracy, but these models still seem to lack an understanding of textual meaning and have difficulty generalizing to completely new contexts. There are reasons to believe that the laws of quantum physics may hold the key to understanding the meaning of natural language [1]. The connection between language structure and the structure of quantum mechanical systems indicates that computers based on the laws of quantum mechanics may be able to process the meaning of natural language better. With the new possibilities that have opened up with the development of quantum information, it makes sense to further explore this possibility.

Until a few years ago, no actual experiments for NLP had been performed on quantum computers, likely because even just representing a sentence requires a decent amount of memory, which cannot fit on today’s quantum computers with only a few qubits. However, recent work [2] has provided a method for sentence classification that can process 5-word sentences using as few as five qubits, which is a common size for current quantum computers. We present an attempt to reproduce this work with simulators freely provided by IBM.

In Section 2, we introduce quantum computers and their rules of operation based on linear algebra. In Section 3, we talk about NLP and algorithms for parsing sentences to capture their grammatical structure. In Section 4, we describe the method for turning these parsed sentences into parameterized quantum circuits with a few examples. Lastly, in Section 5, we describe the process of optimizing the parameters for these circuits using machine learning.

2. Quantum computing

In this section, we provide an introduction to quantum computation, assuming at least a familiarity with linear algebra. For more detail, the book by Nielsen and Chuang [3] is a great resource.

The universe follows familiar patterns, such as how a resting object does not begin moving unless a force is applied. Classical computers use these laws to store, transfer, and process information; however, we know that, at a microscopic scale, the universe also follows quantum rules, which are quite different from these classical rules. Quantum computers, based on these microscopic physical laws, are known to perform some computations much faster than classical computers, and they may even be able to magnify the power of AI. This future potential is part of the great interest in quantum computation.

Quantum computation can be motivated by comparing it with classical (nonquantum) computing. On a classical computer, one can think of the state as determined by a collection of bits, each of which takes the value either 0 or 1 (for example, corresponding to whether a voltage in a certain component is high or low). At each step of computation, the bit values depend on what they were at the previous time step and what operations (or gates) were performed. Examples include the common binary logical connectives, such as the “AND” gate, which outputs a 1 if both inputs are 1 and 0 otherwise. Another common operation is to simply copy bits from one memory location to another. In fact, using the operations of copying and “NAND” (just flipping the outputs of the classical AND gate), one can create an arbitrary function between any two finite collections of bits, given sufficient intermediate storage.

In quantum mechanics, the state of a system is represented differently, so we cannot simply write out a list of 0s and 1s to finitely enumerate all physically possible states for a system. Quantum mechanics is a linear theory and is therefore described by linear vector spaces. In quantum computing, we focus on the simplest nontrivial system, which is described by a complex 2-dimensional vector space whose orthonormal basis vectors we write as $|0\rangle$ and $|1\rangle$, in analogy with the classical bits 0 and 1. We use the convention that physical states have norm 1 under the standard norm, which means that any possible state of the system will be $\alpha|0\rangle + \beta|1\rangle$ where $|\alpha|^2 + |\beta|^2 = 1$. (Even though there are infinitely many such possible states, it is conventional to call this a 2-state quantum system, indicating the number of possible measurement outcomes of any observable.)

Not only is the description of a single qubit state broader than that of a classical bit, but qubits also combine together in a more subtle manner. For a 3-bit classical system, we would say that each bit is either in the state 0 or in the state 1, so the system is in one of $2^3 = 8$ possible states: 000, 001, 010, 011, 100, 101, 110, or 111. When combining 2-state quantum systems, their vector spaces combine in the natural way, a tensor product; given a collection of vector spaces, their tensor product

is a new vector space whose basis elements are identified by choosing one basis element from each of the input vector spaces. Because each subsystem can be in its own state $|0\rangle$ or $|1\rangle$, we can similarly write $|a\rangle|b\rangle|c\rangle$ or $|abc\rangle$ to indicate that the first subsystem is in state $|a\rangle$, the second in state $|b\rangle$, and the third in state $|c\rangle$. So in this 3-qubit example we can write eight basis states $|000\rangle$, $|001\rangle$, $|010\rangle$, $|011\rangle$, $|100\rangle$, $|101\rangle$, $|110\rangle$, $|111\rangle$, and then the possible states for the entire system will be the normalized (norm 1) linear combinations of these $2^3 = 8$ basis states.

An operation or gate on a quantum computer must take physical state inputs to physical state outputs, so, in particular, it must take unit (normalized) vectors to other unit vectors. In the language of linear algebra, this is a unitary transformation, which also maps mutually perpendicular vectors to mutually perpendicular vectors. In the finite dimensional case that we deal exclusively with in quantum computing, a unitary transformation can be expressed as a unitary matrix. Because matrices naturally represent what output vector each of a given basis of input vectors gets mapped to, a common way to think about quantum gates is where they map each standard basis state. An arbitrary such operation could be very complex, causing difficulty both for thinking conceptually about it and for physically implementing it, so we generally focus on basic quantum gates and composing them together. These basic gates are described just in terms of their actions on a few relevant qubits.

As a first example of a quantum gate, one might want to perform an operation on a 2-qubit system for which one of the output bits will always be the AND of the two inputs for all four possible input combinations. However, this is impossible, because $|00\rangle$, $|01\rangle$, and $|10\rangle$ would all have to map into a vector space of dimension at most 2, which is impossible for invertible (and in particular unitary) transformations. So generalizations of natural operations from classical computing are not necessarily natural operations to perform in the context of quantum computing. Instead, one example is the NOT operator, which swaps

$$|0\rangle \rightarrow |1\rangle \text{ and } |1\rangle \rightarrow |0\rangle,$$

which also could be written in matrix form as $\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$.

Another simple 1-qubit gate is the PHASE(θ) operator, which maps

$$|0\rangle \rightarrow |0\rangle \text{ and } |1\rangle \rightarrow e^{i\theta}|1\rangle$$

with corresponding matrix $\begin{bmatrix} 1 & 0 \\ 0 & e^{i\theta} \end{bmatrix}$. Note that PHASE(θ), unlike NOT, has no analog in digital classical computers, where there is no concept of phase.

Slightly more complicated are the “controlled” versions of these gates, which use two qubits: a control qubit and a target qubit. An operation is applied to the target qubit if the control qubit is $|1\rangle$, while no operation is applied if the control qubit is $|0\rangle$. For example, the CNOT operation (with the first qubit as the control and the second as the target) maps

$$\begin{aligned} |00\rangle &\rightarrow |00\rangle, \\ |01\rangle &\rightarrow |01\rangle, \\ |10\rangle &\rightarrow |11\rangle, \\ \text{and } |11\rangle &\rightarrow |10\rangle. \end{aligned}$$

The controlled phase gate, $\text{CPHASE}(\theta)$, is defined similarly, with the last two rows instead being $|10\rangle \rightarrow |10\rangle$ and $|11\rangle \rightarrow e^{i\theta}|11\rangle$. Recall that these gates are still just linear maps defined on our chosen basis vectors, and can therefore also be represented in matrix form. For example, the $\text{CPHASE}(\theta)$ is given by

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & e^{i\theta} \end{bmatrix}$$

Another important gate is the Hadamard gate, taking

$$|0\rangle \mapsto \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \text{ and } |1\rangle \mapsto \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle),$$

or in matrix form, $\frac{1}{\sqrt{2}}[1 \ 1 \ 1 \ -1]$, which is useful because we generally assume that the initial state of any computation is the basis state where every qubit is $|0\rangle$, and so applying the Hadamard gate to every qubit can generate an equal superposition of all possible basis states, for example, $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$ for one qubit or $\frac{1}{2}(|00\rangle + |01\rangle + |11\rangle)$ for two qubits.

Lastly, we introduce x and z rotation gates parameterized by an “angle” θ , which, by analogy with 3-dimensional space, should together be able to rotate a unit vector to any other unit vector:

$$R_x(\theta) = \begin{bmatrix} \cos(\theta/2) & -i \sin(\theta/2) \\ -i \sin(\theta/2) & \cos(\theta/2) \end{bmatrix} \text{ and } R_z(\theta) = \begin{bmatrix} e^{-i\theta/2} & 0 \\ 0 & e^{i\theta/2} \end{bmatrix}.$$

3. Compositional distributional model of meaning

Coecke *et al.* [4] introduced a theory of word meanings that includes both distributional and compositional meaning. Distributional means that a word's meaning is determined by how it is used in a sentence or its position relative to other words. Compositional means that an expression's meaning is determined by the meanings of its individual words and how they are grammatically combined. A prototypical example of the distributional model of meaning is word2vec [5], where words are embedded into a vector space with the embeddings learned such that words that appear in similar contexts are close to each other (meaning that the vector space inner product between them is near 1), and words that are distributed differently in texts get embedded as vectors with small inner products. A natural way of combining arbitrary numbers of vectors is with the tensor product. But this simply represents all the information; it does not take into account grammatical relations between the different words or the compositional meaning in their larger context. To do this in a systematic way, we need a grammatical parsing of the sentence and rules for how the different parts in the tensor product combine based on their grammatical relations.

Coecke *et al.* [4] explain in detail how category theory can formally describe these methods, but the full details are beyond the scope of this project. The essential point is that the combinations can be defined with the use of pregroup grammar (where grammar formally just means a set of rules), which assigns each part of speech a certain string that represents how it joins with other strings.

Taking n to represent a noun, s to represent a sentence, and L and R to represent left and right inverses, respectively, we use the following definitions, explained in more detail below.

$$\text{Noun} \rightarrow n$$

$$\text{Intransitive verb} \rightarrow n^R(s)$$

$$\text{Transitive verb} \rightarrow n^R(s)n^L$$

$$\text{Relative pronoun "who"} \rightarrow n^R(n)s^L n$$

These strings do not make sense on their own, but their combination rules match the grammatical structure of English. The rules we will need are just for deleting instances of symbols beside their inverses, namely $nn^R \rightarrow 1$, $n^L n \rightarrow 1$, and $s^L s \rightarrow 1$. The symbol 1 represents the identity, or empty string, so basically these rules tell us how to delete symbols to simplify type strings.

As the simplest example, we can consider the sentence "Romeo dies," which is a noun followed by an intransitive verb, and therefore has

type $(n)(nR_s)$, which can be reduced to s by applying the rule $nnR \rightarrow 1$. This indicates that “Romeo dies” is a grammatical sentence. Similarly, transitive verbs require both a subject and an object, or a noun on both sides, to form a sentence, which is why they are assigned the string $nRsnL$, and the sentence “Romeo loves Juliet” reduces from $(n)(nRsnL)(n)$ to s as a complete sentence. The most complex part of speech we will deal with is the relative pronoun “who,” which takes a noun type on the left and the predicate type nR_s on the right to yield a noun type result, hence the string $nR(n)sLn$.

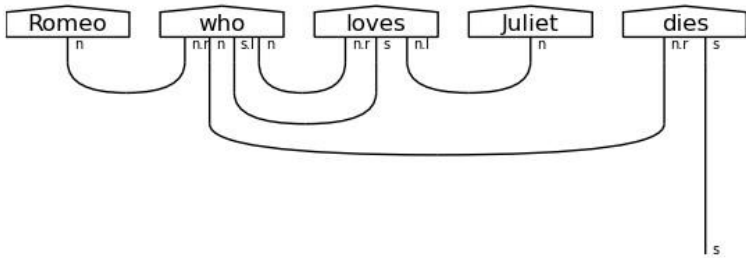


Figure 1: String diagram for the sentence “Romeo who loves Juliet dies,” showing the grammatical connectivity of the sentence, as parsed using the pregroup grammar. This figure was generated using Lambeq [6].

Now as our main example, we parse the sentence “Romeo who loves Juliet dies,” as visualized in Figure 1. Here is the series of reductions:

- $(Romeo)(who)(loves)(Juliet)(dies)$
- $\rightarrow (n)(n^Rns^Ln)(n^Rsn^L)(n)(n^Rs)$ Convert words by part of speech
- $\rightarrow (nn^R)ns^L(nn^R)s(n^Ln)n^Rs$ Rearrange parentheses
- $\rightarrow n(s^Ls)n^Rs$ Delete pairs, add parentheses
- $\rightarrow (nn^R)s$ Delete pairs, add parentheses
- $\rightarrow s.$ Delete pair

More examples of this process are provided in Coecke *et al.* [4] and Meichanetzidis *et al.* [2], and these kinds of diagrams and their applications to quantum mechanics are addressed in much greater detail in Coecke and Kissinger [7].

The idea of representing words as vectors is extremely natural in quantum mechanics, because a quantum system’s state is always

represented by a vector, so any representation of a word on a quantum computer must necessarily be a vector in some sense. Further, the idea that the unprocessed sentence is the tensor product of its constituent words is again so natural that it is just a byproduct of the way quantum systems are composed together. The remaining part is just how we deal with this tensor product state based on the grammatical structure of the sentence.

4. Circuit generation

As is traditional in quantum computing, we begin with the state of all zeroes $|00\dots 00\rangle$. We can then split our circuit into two main parts: first, prepare the state corresponding to each word, and next perform the gates corresponding to the reduction of the sentence in the pregroup grammar. The final step is a measurement.

The circuits drawn in Figures 2, 3, and 4 were created in a Jupyter notebook using Qiskit [8] to run the simulations with IBM's quantum computers (<https://quantum-computing.ibm.com/>). These are read as follows. On the left are labels indicating which parts of the circuit correspond to which words. The whole circuit is read from left to right, showing state initialization, computational operations, and measurements. The initial q_i label the individual qubits, and the black boxes on the left show that the circuit begins in the state of all zeroes. The vertical gray lines are just cosmetic and can be used to divide the circuit into logical groupings. Single boxes represent single-qubit gates, and colored vertical lines between wires represent multi-qubit gates. The blue H represents the Hadamard gate, the plain blue line represents the CPHASE(π) gate, and the blue line ending in a plus sign represents the CNOT gate, where the plus is on the target qubit. The purple Rx and Rz represent x and z rotations, respectively, and the Rz with a purple wire connecting to another qubit represents a controlled z rotation. Notice that these rotations are parameterized by a number, as indicated on the circuit with sample initial values. Lastly, the gauge boxes on the right side indicate a measurement, collapsing the quantum state to get some classical information about it.

The word state preparation (shown on the left part of the circuit) depends on the word's part of speech. For nouns and intransitive verbs (like "Juliet" and "dies"), which really only have one way of relating, we quite simply put in arbitrary gates that allow any state to be made from the starting zeroes. Namely, we put in an x -rotation by θ_1 and z -rotation by θ_2 , that is $R_x(\theta_1)$ and $R_z(\theta_2)$. For a circuit with fewer gates but less accuracy, we may use only one rotation $R_z(\theta)$, as in Figure 2, as opposed to Figure 3. These parameters θ_i are yet unknown, because we do not

know the exact best word embeddings, but by varying them it is possible to prepare any valid state.

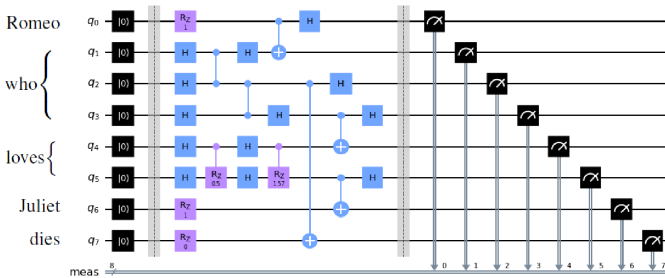


Figure 2: Generated quantum circuit for “Romeo who loves Juliet dies.” In this simplified example, only one rotation (R_z) is used for each qubit.

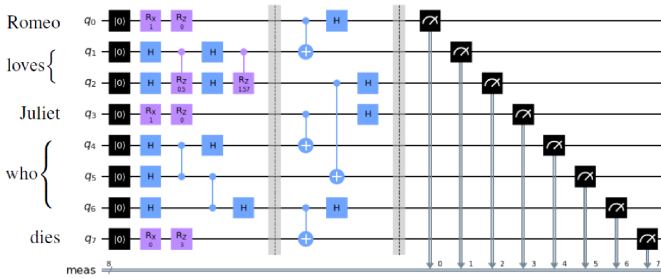


Figure 3: Generated quantum circuit for “Romeo loves Juliet who dies.”

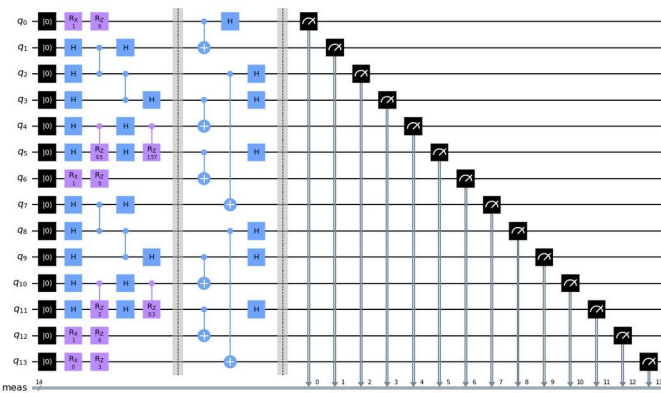


Figure 4: Generated quantum circuit for “Romeo (q_0) who (q_1 - q_3) loves (q_4 - q_5) Juliet (q_6) who (q_7 - q_9) kills (q_{10} - q_{11}) Juliet (q_{12}) dies (q_{13}).”

For other parts of speech, the construction is a bit more complex using more qubits, but the same idea can be applied, where we have a fixed basic circuit structure for preparing the state, just with some parameters on the gates that can be varied to allow preparing arbitrary states. The transitive verb “loves” uses Hadamard gates and controlled parameterized rotations to set up an arbitrary 2-qubit state representing the relationship between subject and object. Lastly, the relative pronoun “who” is assigned a series of Hadamard and CPHASE(π) gates, which set up the GHZ state $\frac{1}{\sqrt{2}}(|000\rangle + |111\rangle)$, a maximally entangled 3-qubit state, representing how this word ties together three different noun descriptions of the same entity. More details on the exact construction used is available in Meichanetzidis *et al.* [2].

Next, we need to perform some operation on this product ensuring that the different grammatical constituents are appropriately related. Meichanetzidis *et al.* [2] make the specification that the s symbols do not appear in the quantum circuit, so we ignore them, and only the n symbol annihilations matter. For these $(nLn) \rightarrow 1$ and $(nnR) \rightarrow 1$ reductions, we use a CNOT followed by a Hadamard gate, and then measure the final state. If the measurement result is $|00\rangle$, this indicates that the two “nounlike” vectors were appropriately correlated. Once all the qubits have been measured, if the final result is all zeroes, then all the meaning vectors match appropriately, and we predict that the sentence is true. Otherwise, something went wrong or there were inconsistent meanings, and we predict that the sentence is false. In practice, we can run the circuit many times, and count the proportion of results where the output is all zeroes, and use this ratio as an estimate of the probability that the sentence is true.

5. Parameter optimization

The only remaining step is to find what parameters our word initialization gates should use. This corresponds to learning the word embeddings, as it is determining what vector the qubits corresponding to each word will be initialized as. To do this, we need a training data set. For this project, we used the data set K_{16} provided in the appendix of Meichanetzidis *et al.* [2]. This has a small vocabulary and several sentences with assignments to `True` (1) and `False` (0) values such that they are logically consistent. Then we can define a loss function as the sum of squared deviations between predicted and actual values:

$$L(\theta) = \sum_{\sigma} (l_{\sigma}^{pr}(\theta) - l_{\sigma})^2$$

where we sum over all sentences σ , l_σ is the actual truth value, and $l_\sigma^{pr}(\theta)$ is the predicted truth proportion using the quantum circuit parameterized with θ .

Because we do not have a closed form solution for the gradient of this loss function with respect to the parameters θ , we require a gradient-free method. We use `minimizeSPSA` from the `noisyopt` Python package, which perturbs the values of θ in a random direction and then compares estimates of the loss function for both possible parameterizations to estimate the gradient and move toward lower loss.

In experiments using the circuits presented here, the loss function did decrease, but not as far as was achieved by Meichanetzidis *et al.* [2]. For the full K_{16} dataset, `minimizeSPSA` got the loss down from 7.2 to 6.0, which was a nonzero amount, but still not quite the <4.0 values (some even near 1.0 in the end) achieved by Meichanetzidis *et al.* [2]. Testing on another set of data, the loss decreased from 3.7 to 2.3 (note that because the loss function is not normalized smaller datasets will have initially smaller loss values in general), but that is still not quite the 70% decreases achieved by Meichanetzidis *et al.* [2], and at the time of writing the exact cause of this discrepancy is still unknown. Perhaps this is due to the choice of parameters in the optimizer `minimizeSPSA`.

6. Conclusion

In this article, we reviewed the principles of quantum computing and explored recent connections made between quantum mechanics and natural language, culminating in the first real NLP algorithm to be run on a quantum computer. We found that this algorithm is simple enough to be run by anyone on IBM's freely available systems. Additional information and source code for the algorithms can be requested from the author at thomas.lee.draper@gmail.com.

As new language models like ChatGPT come out, they certainly show impressive capabilities for mimicking human language, but it may also seem remarkable how easily such an advanced model will contradict itself or say something that makes no sense. Perhaps larger models can solve this problem, but it may also be the case that a new kind of model is necessary for really representing the meaning of language. If Coecke's theory is correct, it may require quantum mechanics to meaningfully represent language in a physical system.

Acknowledgments

I would first like to acknowledge my advisor Jean-François Van Huele, who has provided helpful insights, discussion, and feedback.

Additionally, I acknowledge financial support from the College of Physical and Mathematical Sciences at BYU.

I am grateful for comments and suggestions from an anonymous referee. The idea for this paper originated in a final project for an NLP class taught by Deryle Lonsdale. I acknowledge the use of IBM Quantum services for this work. The views expressed are those of the author, and do not reflect the official policy or position of IBM or the IBM Quantum team.

References

- [1] B. Coecke, “From quantum foundations via natural language meaning to a theory of everything,” <https://arxiv.org/abs/1602.07618> [cs.CL] (2016).
- [2] K. Meichanetzidis, A. Toumi, G. de Felice, and B. Coecke, “Grammar-aware sentence classification on quantum computers,” *Quantum Machine Intelligence* 5 no. 1, (Feb, 2023) 10. <https://doi.org/10.1007/s42484-023-00097-1>.
- [3] M.A. Nielsen and I.L. Chuang, *Quantum Computation and Quantum Information: 10th Anniversary Edition*. Cambridge University Press, New York (2011).
- [4] B. Coecke, M. Sadrzadeh, and S. Clark, “Mathematical foundations for a compositional distributional model of meaning,” <https://arxiv.org/abs/1003.4394> [cs.CL] (2010).
- [5] T. Mikolov, I. Sutskever, K. Chen, G. Corrado, and J. Dean, “Distributed representations of words and phrases and their compositionality,” <https://arxiv.org/abs/1310.4546> [cs.CL] (2013).
- [6] D. Kartsaklis, I. Fan, R. Yeung, A. Pearson, R. Lorenz, A. Toumi, *et al.*, “lambeq: an efficient high-level Python library for quantum NLP,” <https://arxiv.org/abs/2110.04236> [cs.CL] (2021).
- [7] B. Coecke and A. Kissinger, *Picturing Quantum Processes: A First Course in Quantum Theory and Diagrammatic Reasoning*. Cambridge University Press (2017).
- [8] Qiskit contributors, “Qiskit: An open-source framework for quantum computing.” <https://doi.org/10.5281/zenodo.2562111> (2023).

Staring Into the Abyss: The Origins of Serial Killer Behavior

Peyton Kosman

University of Utah

Abstract

The term “psychopath” was first coined in the late 19th century, but it was not until at least the middle to late 20th century that tangible progress was made in understanding this type of distinct personality. In particular, behavioral investigative units were created to study, categorize, and profile such individuals. This paper is the first to provide an exploration of the term “psychopath” as it has evolved in the 20th century with the creation of the Diagnostic and Statistical Manual of Mental Disorders psychiatric evaluative tool, the establishment of the Behavioral Science Unit, and the development of actual profiling techniques for apprehending psychopathic killers. In addition, this study will focus on the origins of psychopathic behavior, specifically the behavior of serial killers. Using grounded theory, the study will examine the histories of specific serial killers across multiple decades to help construct a theory of the origins of serial killer behavior.

Introduction

Friedrich Nietzsche once said, “Whoever fights monsters should see to it that in the process he does not become a monster. And if you

gaze long enough into the abyss, the abyss will gaze back into you” (Ressler and Shachtman 1992). Criminologists, psychologists, and psychiatrists have been fighting human monsters and trying to understand them since the early 17th century. Since then, we have created ways to identify these individuals through their crimes and behaviors. These methods, specifically those of the Behavioral Science Unit (BSU), later the Behavioral Analysis Unit (BAU), were created by the U.S. Federal Bureau of Investigation (FBI) in 1972. The individuals who use these methods are known as profilers, and they use victimology, crime scene photos, and evidence to piece together who they believe the perpetrator of a crime is. Profilers mainly investigate psychopaths, especially the ones that kill. This paper is focused on discovering the origins of psychopathic behavior, particularly the origins of serial killer behavior.

To gain a better understanding of the origins of psychopathic behavior, this research will briefly explore the evolution of the term psychopath and the creation of the Behavioral Science Unit (BSU), discuss the psychopathic traits and background environmental factors common to serial killers, and suggest behavioral cues and patterns in their behavior. This overview will be followed by brief sections on methods and findings, specifically, an analysis of case studies regarding the serial killers selected for this study—a selection that spans several decades. Finally, the paper will close with a discussion section and brief conclusion. The discussion section will focus on using Glaser and Strauss’s grounded theory (1967) as a method of constructing a preliminary theoretical framework based on the analysis of case studies presented in the previous section to explain the origins of serial killer behavior. Grounded theory helps discover or construct theory from already existing data (Glaser and Strauss 1967).

Psychopaths and Those Who Hunt Them

In early 17th-century England, there was little to no knowledge of individuals who were “insane” and how to treat them. As we moved into the early 18th century, medicine still did not recognize psychopathy in its three broad classes of mental health: melancholy (depression); psychosis; and delusion (Kiehl and Hoffman 2011). By 1888, the term “psychopath” had been coined by German psychiatrist J.L.A. Koch (Kiehl and Hoffman 2011). By the early 1930s, clinicians and academics began using the terms “sociopath” and “psychopath” interchangeably. Interestingly, most academics and researchers preferred the term sociopath for two reasons. First, many people believed that psychopathy and psychosis were the same thing, and second, “sociopath” suggested

the notion that these antisocial behaviors were largely the product of environment (Kiehl and Hoffman 2011). During the Great Depression, psychiatry started using the term psychopath to describe people who were depressed, weak-willed, excessively shy, and insecure—simply anyone who seemed “abnormal” (Kiehl and Hoffman 2011).

This lack of clarity on characteristics and vague use of language with regard to psychopaths began to change when, in the late 1930s, Scottish psychiatrist David Henderson and American psychiatrist Hervey Cleckley published their research on psychopaths. Henderson’s book *Psychopathic States* (1951) focused on the psychopath that was “otherwise perfectly normal, perfectly rational, and perfectly capable of achieving his abnormal egocentric ends” (Kiehl and Hoffman 2011). Cleckley’s book *Mask of Sanity* (1941) generated the same ideas, and this caused a minority of psychiatrists to change the way they viewed a psychopath’s central lack of moral reasoning and helped to encourage the use of more diagnostic precision than had been seen before. This new direction in psychiatry and psychopathy led to the creation of what became the “bible” of diagnostic psychiatry, also known as the Diagnostic and Statistical Manual of Mental Disorders (DSM), which was first published in 1952 (American Psychiatric Association 1952). The DSM led to huge strides in the field of psychopathy and psychiatry, creating a structured and more accurate manual that researchers, psychologists, psychiatrists, academics, and law enforcement could use to help with individuals suffering from these behaviors, investigations, research, and more. The DSM would coin the term “antisocial personality disorder” and eventually support using the term “psychopath” in research to describe someone who demonstrates unusual behaviors (Kiehl and Hoffman 2011: 362).

The BSU of the FBI was created in 1972 (Douglas and Olshaker 1999). The unit was created to investigate serial rapists and homicides, and, at the start of the unit, they only had 11 agents (Douglas and Olshaker 1999). In 1976, John E. Douglas joined the team. Douglas would soon become one of the greatest profilers in our era, and his work would help law enforcement all over the world catch dangerous criminals (Douglas and Olshaker 1999). The BSU eventually shifted into the BAU to include the many other crimes that had increased over time (cybercrimes, white collar crimes, etc.). The main tool developed to assist the BAU and other law enforcement agencies in their investigations was profiling (Douglas et al. 2013).

Profiling can be described as a collection of leads, an informed attempt to provide detailed information about a certain type of criminal, and a biological sketch of behavioral patterns, trends, and tendencies (Douglas et al. 2013). Profiling is mainly used to investigate violent

psychopaths, anything from killers and rapists to arsonists, and it helps law enforcement narrow the field of options and generate the best educated guesses about the perpetrator. Douglas and his BAU team created their own manual, called the *Crime Classification Manual*, that they use when profiling criminals (Douglas et al. 1992). In particular, Douglas and the BAU focused on apprehending killer psychopaths, also known as serial killers. A serial killer can be defined as an individual who unlawfully kills two or more victims in separate events (Douglas et al. 2013; Ressler and Shachtman 1992). In the *Crime Classification Manual*, Douglas et al. (2013) break down serial killer crimes, motives, modus operandi, and victimology.

According to the *Crime Classification Manual*, psychopaths are characterized by particular traits, including lack of empathy, lack of remorse, narcissism, manipulativeness, deceitfulness, brazenness, and a grandiose personality, as well as antisocial behaviors and lack of social skills. This is mirrored in the work of Fallon (2013), who identified four categories of psychopathic traits. The first category is the interpersonal factor, whose traits include superficiality, grandiosity, and deceitfulness. The second category is the affective factor, whose traits include lack of remorse and empathy and refusal to accept responsibility for one's own actions. The third category is the behavioral factor, whose traits include impulsivity, lack of goals, and unreliability. The last category is the antisocial factor, whose traits include hotheadedness, a history of juvenile delinquency, and a criminal record (Fallon 2013: 12-13). Fallon noted that these factors can overlap with one another and are associated with mental health issues like anxiety, schizophrenia, and antisocial personality disorder.

In addition, Douglas and his colleagues identified profound environmental factors in the lives of psychopathic killers that comprised similar backgrounds of abuse, including humiliation and degradation, as well as severely dysfunctional homes (Douglas et al. 2013). This is also echoed in a study conducted by Mitchell and Aamodt (2005), who discovered that among the 50 serial killers they evaluated, 68% had experienced some form of maltreatment, 36% were physically abused, 26% were sexually abused, 50% were psychologically abused, 18% were neglected, and 32% were not abused in any form. They discovered that in every category, serial killers surpassed the rate of abuse (all forms) compared with the general public.

In the *Crime Classification Manual*, Douglas et al. (2013) suggest that there is an arc to the behavior of psychopathic killers or serial killers. In this regard, psychopaths kill to fulfill their desire to dominate and control their victims—this is largely in response to a lack of power and control in their past lives. But to realize this desire to dominate and

control, psychopaths create and then begin to play out a fantasy of their intended behavior over a stepwise process that could begin with harming animals and/or children or even voyeurism and then escalate over time to rape and murder of human victims (Ressler and Shachtman 1992; Douglas et al. 2013). Over time, the modus operandi of a particular killer becomes a pattern, which is also dynamic and even malleable for some psychopaths (Douglas et al. 2013).

Psychopaths are some of the most dangerous individuals in our society, particularly because of their lack of empathy, their deceitfulness, and their narcissism (Ressler and Shachtman 1992). This research explores the origins of psychopathic behavior by looking into the histories of serial killers spanning decades. In addition, the use of grounded theory will help to advance a theoretical model for understanding the origins of their behavior.

A Method to the Madness

The purpose of this research is to determine the origins of psychopathic killing using grounded theory. Grounded theory, created by Glaser and Strauss (1967), helps discover or construct theory from analysis of data. The type of research that will be conducted in this study is secondary research. Secondary research is research that involves using already existing data (Stewart and Kamins 1993). This study will use existing case studies and research on the topic of psychopaths, specifically those that kill, to determine the origins of serial killer behavior. This study will use case studies from the past six decades—from the 1960s to 2010s—to highlight killer psychopaths in those eras to understand motives and antecedents to their behavior, specifically the patterns among serial killers with regard to both psychopathic traits and environmental factors. Once a list of serial killers from each decade was created, some killers were excluded because of the lack of information about their childhood and known behaviors. The serial killers selected for this analysis are Edmund Kemper, Ted Bundy, Jeffrey Dahmer, Gary Ridgeway, and Dennis Rader.

Staring into the Abyss

Edmund Kemper

Background

Edmund Emil Kemper III was born December 18, 1948, in Burbank, California (Douglas and Olshaker 1999). He was born into a difficult family, which resulted in his parents divorcing when he was

nine years old. His father ended up moving away, leaving him with his mother and sisters (Ressler and Shachtman 1992). His mother was verbally abusive and judgmental of him. Everything he did seemed like an issue to her and, as a cruel punishment, she would lock him in the basement for days at a time (Wright and Hensley 2003). From an early age, Kemper displayed unusual behaviors. He and his sister would play games taking turns pretending to be in an electric chair or gas chamber, and he would cut off the limbs of his sister's dolls. He transitioned into abusing the family's animals by cutting off the heads of their cats and mutilating their bodies (Douglas and Olshaker 1999). His relationship with his mother became volatile, and eventually he moved to live with his grandparents. There, he faced the same treatment that he had received from his mother, and soon it became too much for him. On August 27, 1964, at the age of 15 years old, Kemper walked up to his grandmother and shot her in the back of the head. He then mutilated her body with a kitchen knife. He then waited for his grandfather to return home, shooting him on the porch (Ressler and Shachtman 1992). Kemper was sent to a mental institution, where he surprisingly convinced the staff that he was "cured" (Douglas et al. 2006). Kemper was released when he was 21 years old and picked up where he had left off, murdering 10 women over the course of the next year.

On May 7, 1973, Kemper was convicted of eight first-degree murder charges and sentenced to life with the possibility of parole. When the judge asked him what type of punishment he believed he deserved, he stated that he believed he deserved "death by torture" (Giannangelo 2012: 89). Kemper is currently imprisoned at California Medical Facility; he is 73 years old.

Psychopathic Traits

When Kemper was arrested in 1964 for the murder of his grandparents, he was taken to a mental institution where he was given a psychological evaluation. According to the evaluation, "he [was] overwhelmed with feelings of worthlessness, guilt, parental rejection, and has great fears that he will suffer a psychotic episode" (Falco 2022: 21). He also claimed he was suicidal and had attempted suicide several times. Throughout his evaluation, he constantly talked about himself and confided that he enjoyed torturing and mutilating small animals, usually his own family pets. Narcissism and the harming of small animals and/or children is consistent with psychopathic behaviors and is also demonstrated in serial killer behavior (Douglas and Olshaker 1999). Kemper's sexual fantasies also started from an early age. According to Martingale (1993), Kemper once stood outside his teacher's house and imagined what it would be like to kill her and make love to her

(Giannangelo 2012). Kemper also acted out these fantasies of strangulation and death on his sister's dolls and even himself, by wrapping a rope around his own neck. Kemper revealed that he used to rip the heads off of his sister's dolls and bury them in his backyard. This fantasy would become reality as Kemper would eventually cut off the head of his victims and bury them in his backyard, a ritual that became part of his *modus operandi* (Giannangelo 2012). When examining Kemper's *modus operandi*, it is clear that psychopathy is present. Kemper would lure his victims to his vehicle or pick them up as they were hitchhiking. He was able to have a conversation and be charismatic, but as soon as they got in the car, he knew what he was going to do. He would either shoot and kill them in his car or take them to a secluded area where he would shoot or strangle them. When they were dead, Kemper would rape them and dismember their bodies. He would keep his victims heads and bring them to his home, which he shared with his mother, and he would bury them in his mother's garden (Giannangelo 2012). Besides Kemper stating that he sometimes suffered from "losing control of his body during his killings" as well as hallucinations, there is little indication that extensive testing was done (Giannangelo 2012: 88).

Environmental Factors

Kemper's childhood was far from perfect. The divorce of his parents and being left with his hostile mother did not help with his mental health issues. Ressler and Shachtman (1992) describes Kemper's family as having "an alcoholic and overbearing mother, an absent father, favored sisters and a grandmother who was in many ways a worse nurturer than the mother" (Ressler and Shachtman, 1992: 249). His mother constantly belittled him and would lock him in their basement if he did not behave the way she wanted him to. She critiqued him about his size as if he could control it and stated it made his sisters uncomfortable and he was a "sexual threat." Although he did have an absent father, his mother did remarry a few times, but the marriages never lasted and she would blame Kemper for their failures (Giannangelo 2012).

Ted Bundy

Background

Theodore Robert Cowell was born November 24, 1946, in Burlington, Vermont. He was born to a single mother, Eleanor Louise Cowell. There is still speculation surrounding his father's identity (Ramslund 2013). When living with his grandparents, Bundy learned that

his biological mother was actually his older sister, which the family had been hiding. At this time, he began to display abnormal behaviors (Douglas and Olshaker 1999). His aunt, Julia, said that she awoke to knives all around her and a three-year-old Bundy standing at the end of the bed watching her. In 1950, Bundy and his mother moved to Tacoma, Washington, for a fresh start (Ramsland 2013). Bundy was known in high school to peers as a “well liked and well known” guy and was pretty average (Douglas and Olshaker 1999: 33).

Bundy was in and out of school from the middle of the 1960s to the middle of the 1970s (Williams 2019). In 1974, Bundy would kidnap and murder his first victim. This murder would begin a four-year spree of kidnapping, torturing, and murdering over 20 victims (Douglas and Olshaker 1999; Ressler and Shachtman 1992). During this time, he would be arrested and then escape custody, only to continue killing. On February 15, 1978, while being pulled over for having the headlights of his car turned off late at night, Bundy was finally arrested and charged with two counts of first-degree murder and three counts of attempted murder (Douglas and Olshaker 1999).

Bundy was sentenced to death following his trial. He had never officially confessed to his murders and had only talked about them in third person so as to allude to what he *thought* the killer did (Ressler and Shachtman 1992). On January 24, 1989, Ted Bundy was executed by the electric chair in a Florida State Prison at the age of 42 years. Bundy confirmed 20 of his victims and had more than 30 possible victims.

Psychopathic Traits

From an early age, Bundy demonstrated behaviors that have been linked to psychopathy. He was exposed to pornography at an early age, and his sexual fantasies developed from there (Giannangelo 2012). An early interest in violence was demonstrated by the incident with his aunt (Douglas and Olshaker 1999). Growing up, Bundy had a hard time socializing with others, including his own half siblings. His stepdad said that he was never interested in spending time with the family (Michaud and Aynesworth 1989). In interviews after his arrest, he told interviewers that he did not understand the concept of social interactions and why people wanted to be friends with one another (Williams 2019). These traits demonstrate antisocial personality disorder, which was explained more as he grows into adulthood. We can see how his personality shifts from quiet and introverted to outgoing and charming. After he was arrested for the murders in Florida, he did an interview with a psychiatrist where he was deemed to be narcissistic (Ressler and Shachtman 1992). His *modus operandi*—the kidnapping, torturing, killing, and mutilating of young women—demonstrated persuasive patterns of grandiosity, both

in his fantasies and behaviors, with a distinct lack of empathy, all which are factors of psychopathy.

Environmental Factors

Bundy, for the most part, had a normal childhood, but one event could be linked to his behavior. Bundy discovered that his sister was actually his mother, which many speculate created a severe attachment disorder that could have impacted his ability to make emotional connections with others, specifically women (Michaud and Aynesworth 1989). This is apparent based off his crimes and modus operandi. Each of Bundy's victims were uncannily similar; they were each brunette and had close facial structures. Because of the way he bludgeoned or strangled them to death, it seems possible he was taking out his anger on someone who resembled these victims. Sadly, Bundy was good-looking, and many of his classmates stated he was a "normal and nice kid," which helped him in the commission of his crimes (Douglas and Olshaker 1999: 33). Some of Bundy's victims who escaped or survived the attacks stated that he approached them asking for help and usually presented himself as injured (Douglas and Olshaker 1999). They stated he was kind, charismatic, and handsome, which eventually gained their trust (Giannangelo 2012). This was also part of Bundy's modus operandi, but it also demonstrates the psychopathy within him. He was grandiose and deceitful towards these women because he knew what he was going to do to them, and he had no remorse.

Jeffrey Dahmer

Background

Jeffrey Lionel Dahmer was born May 21, 1960, in Milwaukee, Wisconsin. He was the oldest son of Joyce Annette, a teletype machine instructor, and Lionel Herbert Dahmer, a chemistry student turned research chemist (Terry 1994). When Jeffrey's mother was pregnant with him, she endured a difficult pregnancy that resulted in her having to take up to 26 pills a day (Ressler and Shachtman 1992). For the most part, Dahmer seemed to have a normal childhood, but this took a drastic turn when his parents separated and his father, as an attempt to bond, introduced him to a "hobby," which would grow into a very dark fantasy.

Dahmer's father introduced him to experimentation on roadkill. Dahmer and his father would collect roadkill and dissect and dissolve the bodies in different acids (Douglas and Olshaker 1999). When Dahmer's parents' relationship ended, his father became more distant, and this hobby would consume him and grow into fantasies. His growing fantasy

included dominating a male victim, dissecting him, and eating him; he especially became fascinated with the chest area (Douglas and Olshaker 1999). Three weeks after his high school graduation, Jeffrey murdered his first victim. For the next nine years, Jeffrey was erratic—he went to school and dropped out, joined the military and was quickly discharged, moved in with his grandmother, and eventually, would turn back to murder. From September 1987 to 1991, Dahmer would murder 16 more young men (Ressler and Shachtman 1992). He evaded arrest numerous times until July 22, 1991, when his last potential victim escaped and waded down police. Police went to Jeffrey's residence, where they discovered Polaroid photos of his victim's bodies, numerous of the victim's heads, and other body parts (Douglas et al. 2006). On February 15, 1992, Jeffrey was sentenced to 16 life imprisonments without the possibility of parole. On November 28, 1994, Jeffrey was discovered in the prison bathroom with numerous injuries and died a few hours later (Terry 1994). Jeffrey Dahmer killed 17 young men in the short 34 years of his life.

Psychopathic Traits

Jeffrey Dahmer's mother had a difficult pregnancy when pregnant with him. She had nausea, vertigo, headaches, and physical issues that eventually led to her being prescribed morphine and phenobarbital. The drug phenobarbital has been linked to birth defects (Chéze 2009). Growing up, his parents constantly were fighting, and Dahmer would seek refuge in his bedroom. At school, his classmates would describe him as shy and antisocial and said he preferred solitude rather than interacting with others. These early signs of antisocial behavior have been linked to psychopathy (Kiehl and Hoffman 2011). Further, his father's attempts at bonding would teach Dahmer how to dissect and experiment with roadkill. Although the animals were already dead, the mutilation and experimenting with acid and other substances demonstrate harm to animals, which is consistent with serial killer behavior (Douglas et al. 2013). While in high school, Dahmer would realize that he was gay and began to experiment with his sexuality. The combination of experimenting with roadkill and his sexuality would lead him to develop a concerning sexual fantasy of killing and dissecting dominant males. As Ressler and Shachtman (1992) and Douglas et al. (2013) demonstrate, the development of sexual fantasies is consistent with serial killer behavior. The end of his senior year is when Dahmer murdered his first victim. From there, he began his spree of killing and eating young men and eventually was caught when one of them escaped. After his arrest and ultimately his death, psychologists would agree and disagree about his mental illnesses and behaviors. They all agree that he

suffered from mental illnesses, but diagnoses would range from being on the autism spectrum to a sexual disorder that caused him to not know right from wrong. He suffered from substance abuse, and most of the time he was drunk when he murdered his victims. Psychologists described him as a necrophiliac, a cannibal, and delusional, and as someone with aggression and rejection issues. It is clear that Dahmer demonstrated psychopathic traits, from his lack of remorse in killing his victims to him consuming his victims; moreover, he demonstrated no empathy at all (Douglas et al. 2013). Needless to say, Dahmer suffered heavily from mental and behavioral disorders.

Environmental Issues

The extent of Jeffrey Dahmer's environmental issues has to do with his parents. His mother, who was in and out of psychiatric care, would always blame Dahmer for her mental health issues as well as her relationship issues with Dahmer's father (Chéze 2009; Palermo and Bogaerts 2015). Dahmer's father was not really involved in Dahmer's early life but had introduced Dahmer to his interest: experimenting with roadkill (Giannangelo 2012; Douglas and Olshaker 2019). As his father started distancing himself from the family after the divorce, Dahmer would continue these experiments until his senior year of high school. His father's introduction to experimenting with roadkill would allow him to develop the skills to produce his *modus operandi*. In high school, Dahmer was quiet and kept to himself but began to try to impress his classmates by acting out in what he thought were "funny" ways. He would scream and pretend to have seizures, which would earn him the title "doing the Dahmer" (Palermo and Bogaerts 2015: 1567). For a period of time, he enjoyed making his classmates laugh because he thought they were friends, but over time he realized they just were laughing at him. The constant neglect and embarrassment he felt from his family and students at school drove him into deeper and deeper isolation, until that loneliness turned into anger and aggression and, soon enough, he was killing his first victim (Palermo and Bogaerts 2015). His *modus operandi* was to charm young boys and men to come to his apartment, where he would drug them, take photos of them while they were unconscious, kill them, and mutilate their bodies to experiment with and even consume them. His ability to charm and lure his victims to his apartment and his switch to lack of remorse and empathy to brutally kill and mutilate them demonstrates psychopathy.

Gary Ridgway

Background

Gary Leon Ridgway was born February 18, 1949, in Salt Lake City, Utah. He was the middle child of three boys born to his mother and father Mary and Thomas Ridgway (Rule 2004). Ridgway's mother was known to be hostile and verbally, physically, and sexually abusive to her sons. Ridgway was also a frequent bedwetter. His mother, after every incident, would wash his genitals aggressively (Rule 2004). From an early age, Ridgway fantasized about torturing and killing his mother because of her abuse towards him, his brothers, and his father. This fantasy soon morphed into a sexual attraction towards his mother. Ridgway would hurt small animals and children and set small fires in his neighborhood (Douglas and Olshaker 1999).

In July 1982, Ridgway killed his first victim; Wendy Caulfield was 16. She was found floating in Washington's Green River. Wendy, like most of Ridgway's victims, was a sex worker in the area (Douglas and Olshaker 1999). In the following weeks, four more bodies were found in the river, and, for the next two decades, police would discover the bodies of 44 more women in the Green River. On November 30, 2001, Gary Ridgway was arrested in connection with four of the murdered women. In custody, he confessed to having 71 victims. On December 18, 2003, Ridgway was sentenced to 48 life sentences without the possibility of parole (Douglas and Olshaker 1999). Gary Ridgway is currently being held at the Washington State Penitentiary; he is 73 years old.

Psychopathic Traits

There is very little information about Gary Ridgway's behavior or psychopathic behaviors before his arrest. What we do know is that Ridgway had low self-esteem because his family was constantly moving, and he had a hard time developing relationships with others. He was a constant bedwetter, even into teenage years, and his mother would embarrass him for it. Bedwetting has been linked to serial killer behavior, specifically bedwetting in teenage years (Douglas and Olshaker 1999). After his arrest, Ridgway was evaluated by a psychiatrist who determined that he suffered from "diffuse organic brain damage" (Sharma 2018: 61), potentially as a result of inhaling the lead paint and other fumes from his work as a painter. Ridgway would drive up and down Seattle's strip, which was known for its abundance of sex workers. He would pick them up and drive them to his home, where he would rape and strangle them. Later, he would dump their bodies along or in the Green River. Ridgway's lack of remorse and disregard for his victims'

bodies demonstrates that he viewed women as objects. Moreover, he demonstrated brazenness in dumping the young women he murdered along the river (Jensen and Case 2011). Law enforcement and psychologists determined that he needed to feel in control and had a desire for power, which is why he would hire sex workers to talk to them, and then murder them (Sharma 2018).

Environmental Factors

Ridgway's family did move around a lot while he was growing up, which made it difficult for Ridgway to develop relationships and also made him have low self-esteem (Jensen and Case 2011). Ridgway's relationship with his mother was the start of his hatred of women. Ridgway's mother was verbally, physically, and sexually abusive to her sons (Rule 2004). Ridgway's first wife was also unfaithful to him. This culmination of being constantly powerless in his relationship with women is evident in his *modus operandi*. Ridgway's process of abducting and murdering women is also consistent with psychopathy (Sharma 2018).

Dennis Rader

Background

Dennis Lynn Rader was born March 9, 1945, in Columbus, Kansas (Anderson 2014). He was the oldest of four boys born to his parents Dorothea Mae and William Elvin Rader (Anderson 2014). From a very young age, Dennis displayed very abnormal behaviors and had very violent sexual fantasies. His main fantasy was torturing women, and he had a fascination with cross-dressing. He frequently would steal his neighbors' clothes and underwear and masturbate into them, and he often watched his neighbors change through their windows (Douglas and Dodd 2008). He also displayed signs of psychopathy by torturing, killing, and hanging small animals. He enjoyed taking ropes and binding his own neck and arms to cut off his circulation (Douglas and Dodd 2008).

On January 15, 1974, the Otero family's bodies were found in their home in Wichita, Kansas. The four victims were Joseph Otero (age 38 years), Julie Otero (33), Joseph Otero Jr. (9), and Josephine Otero (11). They were discovered by Joseph and Julie's three oldest children, who were at school at the time of the murders (Ramsland 2016). Rader's next attack occurred on April 4, 1974, when he murdered Kathryn Bright and attacked her brother Kevin, who would survive (Ramsland 2016). Between 1977 and 1991, he killed three more people. During his cooling-

off periods, he would taunt police, the media, and potential victims. He would call the police to report his murders, send letters and poems to television stations, and also sent letters and poems to his potential victims (Douglas and Olshaker 1999).

In 2004, Rader returned to public awareness by sending letters to newspapers, television stations, and the police. This communication back and forth lasted a year and eventually led to his arrest in February 2005 (Douglas and Dodd 2008). The FBI and local authorities discovered that Dennis was the author of these letters using DNA from his daughter's pap smear from records at Kansas State University to compare the DNA found at the crime scenes (Ramsland 2016). On February 25, 2005, Dennis was arrested while driving near his home. He pleaded guilty to 10 counts of first-degree murder and was sentenced to 10 consecutive life. Dennis Rader, the "BTK Killer" (Bind, Torture, Kill) had killed 10 people in the span of 17 years. He is still in prison and is 77 years old (Anderson 2014).

Psychopathic Traits

Dennis Rader fits many of the traits of a psychopath. When he was a child, he admitted that when he was a child, he used to torture animals by hanging them by their necks in his barn and masturbating next to them. His sexual fantasies began as a child where he would fantasize about tying up his female classmates and harming them. These sexual fantasies and obsessions turned into stalking and breaking into homes to steal jewelry and underwear. To fulfill these desires, he would dress up in women's clothes and handcuff/tie himself up with ropes and take photos of himself in different positions. As his sexual fantasies continued, they could no longer be satisfied by taking photos and breaking into houses, and they evolved into murder. When he was arrested in 2005, he told investigators and psychologists that he could not control his behaviors and emotions, but in fact it was a demon called 'Factor X' that controlled him. Investigators knew it was an excuse to cover up for his own behavior, and they diagnosed him with antisocial personality disorder and obsessive compulsiveness disorder. They described him as someone without a conscience, no guilt, having a need for power and control, and feeling a lack of responsibility for his actions, which are all clear characteristics of psychopathy. The fact that Rader was able to live two separate lives—a psychopathic killer and a religious family man—speaks to his psychopathy and antisocial personality disorder (Giannangelo 2012).

Environmental Factors

Unfortunately, there is not a lot of evidence or historical knowledge of Rader's relationship with his family. We do not know whether Rader suffered from any sort of abuse when he was younger. According to Leary et al. (2023), the level of brutality of Rader's crimes demonstrates some history of substantial abuse. Because we know Rader has sexual compulsions, the two factors investigators suggest could have sparked his interests were watching his grandmother twist the necks off of chickens that they were eating for supper and being disciplined by his mother in a demeaning manner by hitting him on the bottom (Giannangelo 2012).

Discussion

This analysis foregrounded the case histories of five notorious serial killers in an attempt to identify antecedents or origins of their behavior. The analysis demonstrates unequivocally that each serial killer exhibited psychopathic traits, including lack of empathy, lack of remorse, grandiose behavior, narcissism, antisocial behavior, and deceitfulness. Sexual fantasies were consistent among each of these individuals and played a part in each modus operandi. For example, Jeffrey Dahmer dissected roadkill, imagining it was a male victim under his control, and those fantasies eventually became reality. The traits and fantasies align with the characteristics of psychopaths, especially serial killers. Along with psychopathy, it is clear that each man faced unique environmental factors. Ed Kemper and Gary Ridgway had complicated and appalling relationships with their mothers, which can be seen reflected in their crimes. Jeffrey Dahmer had absent and unsupportive parents, which contributed to his antisocial behavior.

Although environmental factors have been linked to serial killers, it is interesting to evaluate Ted Bundy and Dennis Rader. For both of these individuals, the evidence of clear abuse is inconclusive and inconsistent. There are small factors within each of their backgrounds that could be considered forms of abuse but not to the extent as the other individuals in this study. This leads to a few telling questions. Why did Bundy and Rader become serial killers despite inconclusive findings on environmental factors? And why is it that some individuals who may have horrific histories of abuse do not become serial killers? Grounded theory could point the way to an answer.

Grounded theory (Glaser and Strauss 1967) allows us to look at the data itself and postulate a theory based off that data. The current study found psychopathic traits in each of the cases histories of our five serial killers; however, there were a few discrepancies that left room for

speculation. Interestingly, John Douglas, the groundbreaking FBI agent who helped create the BSU and developed the art of profiling psychopaths, offers an answer to our two questions, offering a particular grounded theory that is consistent with our findings and that I will call the Douglas Duality Theory. Douglas speculates (Douglas and Olshaker 1999) that for an individual to develop into a serial killer and develop psychopathy itself, two factors must be present—a biological predisposition coupled with environmental factors. This means that some individuals may experience terrible levels of abuse, but they may never develop into a serial killer because there is no biological predisposition. On the other hand, a person who may not have experienced severe abuse—not to the extent discussed with some of these killers—might have a clearer or stronger biological predisposition to psychopathy. For the latter, the abuse might not have to be as extensive or extreme but perhaps only emerges after something like a triggering factor. This would account for the behavior of both Ted Bundy and Dennis Rader, who are outliers only with regard to environmental factors.

Conclusion

Research on psychopaths and serial killers, in particular, is important because it can help us understand them and, ultimately, help prevent other individuals from following this horrific path. Douglas and Olshaker (1999) posit that knowing more about the origins of serial killer behavior can help us craft programming for youth and children who come from these backgrounds who might potentially start to exhibit such behavior. We have formed a better understanding of psychopaths since the early 17th century, but we are still learning. Individuals who study vulnerable populations like this have a daunting task. While they study psychopaths, they look into an abyss of darkness and that darkness stares right back at them.

References

American Psychiatric Association. (1952). *Diagnostic and Statistical Manual of Mental Disorders* (1st ed.). American Psychiatric Association.

Anderson, P. (2014). Dennis Rader—aka the “BTK Killer”—wanted his nickname on the list of the world’s worst serial killers. *The Herald Sun*, October 7, 2014.

Chéze, E. (2009). *Jeffrey Lionel Dahmer: A Psychobiographical Study*. Master's thesis. Nelson Mandela Metropolitan University.

Cleckley, H. (1941). *The Mask of Sanity: An Attempt to Reinterpret the So-called Psychopathic Personality*. C.V. Mosby Co.

Douglas, J., and J. Dodd. (2008). *Inside the Mind of BTK: The True Story Behind the Thirty-year Hunt for the Notorious Wichita Serial Killer*. Jossey Bass.

Douglas, J.E., Burgess, A.W., Burgess, A.G., & Ressler, R.K. (Eds.). (1992). *Crime Classification Manual*. Lexington Books/Macmillan.

Douglas, J.E., et al. (2006). *Crime Classification Manual*. Jossey-Bass.

Douglas, J.E., and Olshaker, M. (1999). *The Anatomy of Motive: The FBI's Legendary Mindhunter Explores the Key to Understanding and Catching Violent Criminals*. Pocket.

Douglas, J.E., & Olshaker, M. (2019). *The Killer Across the Table: Unlocking the Secrets of Serial Killers and Predators with the FBI's Original Mindhunter*. HarperLuxe.

Falco, C. (2022). Edmund Kemper stories. Retrieved July 21, 2022, from <http://edmundkemperstories.com/>.

Fallon, J.H. (2013). *The Psychopath Inside: A Neuroscientist's Personal Journey into the Dark Side of the Brain*. Current.

Giannangelo, S.J. (2012). *Real-Life Monsters: A Psychological Examination of the Serial Murderer*. Praeger.

Glaser, B.G., and Strauss, A.L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine de Gruyter.

Henderson, D. (1951). Psychopathic states. *British Journal of Delinquency*, 2(2), 84–87.

Jensen, J., and Case, J. (2011). *Green River Killer: A True Detective Story*. Dark Horse Books.

Kiehl, K.A., and Hoffman, M.B. (2011). The criminal psychopath: history, neuroscience, treatment, and economics. *Jurimetrics*, 51, 355-397.

Leary, T., Aamodt, M., Walsh-Haney, H., Thomas, D., Baer, E., Girimurugan, S.B., Ellis, J., Dunbar, M., and Fenuccio, B. (2023). Radford/FGCU serial killer research. Retrieved March 15, 2023, from <https://www.fgcu.edu/skdb/>.

Martingale, M. (1993). *Cannibal Killers: The History of Impossible Murderers*. Carroll & Graf Publishers.

Michaud, S.G., Aynesworth, H., and Bundy, T. (1989). *Ted Bundy: Conversations with a Killer*. Authorlink Press.

Mitchell, H., and Aamodt, M.G. (2005). The incidence of child abuse in serial killers. *Journal of Police and Criminal Psychology*, 20, 40–47.

Palermo, M.T., and Bogaerts, S. (2015). The dangers of posthumous diagnoses and the unintended consequences of facile associations: jeffrey dahmer and autism spectrum disorders. *International Journal of Offender Therapy and Comparative Criminology*, 59(14), 1564–1579.

Ramsland, K. (2013). The many sides of Ted Bundy. *Forensic Examiner*, 22(3), 18.

_____. (2016). *Confession of a Serial Killer: The Untold Story of Dennis Rader, the BTK Killer*. ForeEdge.

Ressler, R.K., and Shachtman, T. (1992). *Whoever Fights Monsters*. St. Martin's.

Rule, A. (2004). *Green River, Running Red: The Real Story of the Green River Killer, America's Deadliest Serial Murderer*. Gallery Books.

Sharma, M. (2018). *The Development of Serial Killers: A Grounded Theory Study*. Master's thesis. Eastern Illinois University.

Stewart, D.W., and Kamins, M.A. (1993). *Secondary Research: Information Sources and Methods*. Sage.

Terry, D. (1994). Jeffrey Dahmer, multiple killer, is bludgeoned to death in prison. *The New York Times*. November 29, 1994.

Williams, D. (2019). Is serial sexual homicide a compulsion, deviant, leisure, or both? Revisiting the case of Ted Bundy. *Leisure Sciences*, 42(2), 205-223.

Wright, J., and Hensley, C. (2003). From animal cruelty to serial murder: Applying the graduation hypothesis. *International Journal of Offender Therapy and Comparative Criminology*, 47(1), 71-88.

Sisters in Struggle: The Resistance of Women in Hip Hop

Theresa A. Martinez

University of Utah

Abstract

Women have played an integral role in all manifestations of hip hop culture from its roots in the 1970s to the present, including breakdancing and graffiti, but particularly rap music. In fact, women rappers have shaped the genre from the very beginning. In particular, although rap music has continued to serve as a reflection on and weighty cultural critique of profound disparities facing African Americans and other people of color in America, it has also offered insights into the lives of Black women. In this regard, the lived experiences of Black women surviving within this context have been echoed in the voices of women hip hop artists who reflect on everything from misogyny to domestic violence to social justice. This paper focuses on a lyrical and thematic analysis of the work of four women hip hop artists—two legendary hip hop artists who emerged in the late 1980s and two contemporary hip hop artists who are already making a mark on the genre—as they communicate and reflect on their sociohistorical context. The thematic and lyrical analysis of our four hip hop artists will be unpacked through a theoretical lens that draws on oppositional cultures or cultures of resistance within the foundation of a Black women’s standpoint—voices of resistance to intersecting oppressions in their time.

INTRODUCTION

As hip-hop made platinum and gold out of an art form born from racism and poverty—and gave power to black men to run a culture they could finally call their own—the women within it battled twice as hard to even be recognized. (Hope 2021)

In her pioneering, comprehensive, and enlightening book *The Motherlode: 100+ Women Who Made Hip-Hop*, Clover Hope (2021) starts out with a question—who was the first woman rapper? She then accentuates the tension in this question by proceeding to lay out a longstanding and at times heated debate about who the first woman MC might be, featuring the rappers Pebblee Poo, MC Sha-Rock, and Debbie D. Yet, interestingly, Hope does not merely proceed to an unequivocal answer, but instead allows her readers to take in the whole complex story of claims and counterclaims and thereby unfolds a candid homage to the “first women” in the genre with featured essays and telling factoids along with beautiful illustrations of the artists by Rachelle Baker. In the end, Hope concludes that the question remains unresolved but allows the facts and the claims of each artist to speak to their extraordinary initiative, outstanding creativity, and hard-earned legacy. Hope notes that some “titles are never up for debate (there’s only one Queen of Soul, and it’s Aretha Franklin), and some are hedged with ambiguity” (10) as is clear of the question she first poses. Yet she reminds the reader that although the “arguments and technicalities could be written off as petty...in their hashing out all the facts, the tension is what forms a more concrete version of history—a collection of firsts—even if these disputes go on forever and ever until the end of time” (10).

The history of women in hip hop is a timely and significant backdrop to the current study. These artists lived, worked, and survived within profoundly disenfranchised communities, facing multiple axes of oppression including racism, sexism, and classism, among so many other sources of disparity. This paper is an exploration of the lyrics of four African American women hip hop artists whose voices rise in formidable resistance to the status quo both from the dominant mainstream and from within their communities. The paper contributes to our understanding of the work of women in hip hop from the late 1980s as well as our current times through a theoretical lens evocative of what Bonnie Mitchell and Joe Feagin presented as “oppositional cultures” and what Patricia Hill Collins describes as “a Black women’s standpoint” (Mitchell and Feagin 1995: 68; Collins 2022: 6). Our four women hip hop artists, as we will discover, voice resistance messages as they speak to their survival within

an American landscape of intersecting oppressions—the sociohistorical context of Black women in America.

SITUATING HIP HOP WITHIN AN OPPOSITIONAL STANDPOINT

Mitchell and Feagin (1995) suggest that *oppositional cultures* or *cultures of resistance* arise among disenfranchised peoples who resist oppression by drawing on their own rich cultural histories and knowledge bases. Mitchell and Feagin assert that oppositional cultures “operate to preserve dignity and autonomy” among the marginalized and “to provide an alternative construction of identity (one not based entirely on deprivation)” (68). More than that, these researchers suggest that oppositional cultures serve to “give members of the dominant group an insightful critique of their own culture” (69). Oppositional cultures can mean everything from creating social movements to leaning on kinship networks, but Mitchell and Feagin also emphasize that much oppositional culture is a people’s use of “their own art and music, and their own philosophical and political thinking about oppression and liberation” (73).

Patricia Hill Collins (2022) describes Black feminist thought as both arising from and aiming to “articulate a Black *women’s* group standpoint regarding experiences associated with intersecting oppressions” of race, gender, class, sexuality, and nation, among others (37). Collins further notes that such intersecting oppressions are central to Black women’s lived experiences within what she identifies as a “legacy of struggle which constitutes one of several core themes of a Black women’s standpoint” (35). More than that, Collins states that Black feminist thought’s “identity as a ‘critical’ social theory lies in its commitment to justice” (13). Among the numerous contributors to Black feminist thought, according to Collins—which includes poets, biographers, writers, and storytellers—are Black women music artists. Collins notes that many forms of African American music, including “[s]pirituals, blues, jazz, rhythm and blues, and progressive hip hop” are part of a continuum of Black women’s resistance music (360).

It is the central argument of this paper that our selected women hip hop artists shaped and nurtured powerfully crafted oppositional messages within their music, messages that speak to autonomy and dignity, but also weighty critiques of the status quo both within and outside their communities. Moreover, these hip hop artists articulate and reflect on multiple axes of oppression in the lives of Black women, reflecting a legacy of struggle—a group consciousness that has historically been silenced.

WOMEN IN HIP HOP

Since the inception of hip hop in the early 1970s, scholars and writers have reflected on its various aspects, including graffiti and breakdancing, but particularly rap music, and a thread of the extensive literature on the genre of rap music focuses on women hip hop artists and their wide-ranging contributions within the genre (Rose 1994; Morgan 1999; Hope 2021). Gwendolyn Pough (2004) is most interested in the rhetoric of “wreck” in hip hop—indicating everything from skill on the microphone—“Check it while I wreck it”—to reflections on damage already done—“Damn, Mother Nature brought wreck” (76-77). But Pough’s major focus is on “wreck” as “a rhetorical tool that builds on Black womanist traditions” within hip hop culture, offering “new possibilities for the potential of Black women’s speech and action” (76). Most importantly, Pough distinguishes hip hop as a genre through which “a generation of Black women is coming to voice and bringing wreck”—privileging Black women’s voices within the sociohistorical context of hip hop (87).

Phillips et al. (2005) argue that women rappers have maintained a “dually oppositional stance” within hip hop—both critiquing the sexism of men in their community and expressing solidarity with men in their community “against mainstream society’s racism, classism, and race-d sexism (which affects both women and men of color)” (255). Robin Roberts (1991) analyses a series of rap music videos featuring Black women rappers and finds that these artists “draw on rap specifically as a black art form to resist racism” but also sexism, and in fact, evoking “the spectres of racism and sexism enables” these artists to attack these forms of oppression “more effectively” (142). Cheryl Keyes (2000) suggests that Black women rappers have been creating empowering spaces within hip hop since its beginnings—“spaces from which to deliver powerful messages from Black female and Black feminist perspectives” (255). Keyes identifies distinct categories of women rappers in her analysis, including the “queen mother” rappers who are often “African-centered,” intellectual, and “demand respect not only for their people but for Black women” (257) as well as the “fly girl” rappers who wear clothes that highlight “aspects of Black women’s bodies considered undesirable by American standards of beauty” and portray themselves in performance as “an independent woman, but additionally, an erotic subject rather than an objectified one” (260).

Tricia Rose (1994) describes the sociohistorical context of early hip hop as characterized by “social isolation, economic fragility, truncated communications media, and shrinking social service organizations” (33-34). Rose notes that young Black women hip hop artists, within this

context and well into the 1990s, address questions of “sexual power, the reality of truncated economic opportunity, and the pain of racism and sexism” (146). Much later and into the 21st century, Rose (2008) will continue to assert the horrific realities still facing Black communities, including “police targeting, racially motivated escalations of imprisonment, and reductions in support of what are still mostly segregated deeply unequal schools” (3) but will, in addition, decry the rampant sexism in the genre and the fact that “the women who have been elevated as mainstream commercial rappers in the past ten years generally follow the larger pattern of hyper-sexualized, objectified terms reserved for black women in the genre” (123).

In all, the literature speaks to several noteworthy threads with regard to women in hip hop. The literature underscores the central importance of hip hop culture as a means for Black women hip hop artists to come to voice as they speak to their lived experiences. The literature also speaks to navigating within a sociohistorical context of racism and sexism—sexism from the dominant culture but also within Black communities—as Black women rappers position themselves in a variety of modes and styles in their engagement with domination. Finally, the literature reminds us of ongoing horrific realities facing Black communities in America with far-reaching implications as women in hip hop continue to speak to stories of the disenfranchised living within intersecting oppressions.

THE METHOD

The preceding discussion of the literature clearly illustrates the significance of the work of Black women hip hop artists who more than anything “interpret and articulate the fears, pleasures, and promises of young black women whose voices have been relegated to the margins of public discourse” (Rose 1994: 146). The current paper will focus on a thematic and lyrical analysis of the work of four hip hop artists—two who emerged in the late 1980s and two contemporary artists. They are Lana Michelle Mooror, better known as MC Lyte, Dana Elaine Owens, better known as Queen Latifah, Marianna Evans, better known as Rapsody, and Assata Perkins, better known as Sa-Roc. These artists reflect on intersecting oppressions in the lives of Black women and proffer oppositional voices to domination in various forms. The artists were selected because of their particular relevance to their times and with regard to the political nature of their work (Pough 2004; Hope 2021; Pearce 2019; Feldman 2022).

The present study examines the lyrics of the selected artists using an analytical rubric whereby “analysis is conceived as an emergent

product of a process of gradual induction...very much a creative act” (Lofland and Lofland 1995: 181-182). More specifically, this analysis will explore the works of these hip hop artists by unpacking common themes and tropes in the lyrics of selected songs. Shulamit Reinharz emphasizes that “qualitative sociologists apply an inductive, interpretive framework to cultural artifacts. What differentiates sociologists from historians is simply the use of sociological theory as an aid in the explanation” (1992: 159). Very much along these lines, this analysis will be deliberately framed by our theoretical lens as we explore lyrical resistance in the work of our selected artists whose oppositional critiques will pivot the center of the discourse to the voices of Black women, speaking within a sociohistorical context of intersecting oppressions.

BLACK FEMINIST THOUGHT

The hip hop artists chosen for this analysis speak to their specific sociohistorical contexts—whether from the 1980s or in the current climate—through critically conscious, evocative, and at times biting lyricism. Our selected artists summarily extend messages of critique of the dominant group, whether that group conjures white privilege or male privilege—offering “members of the dominant group an insightful critique of their own culture” (Mitchell and Feagin 1995: 69). More than that, the lyrics of our artists stand as witness to a “legacy of struggle” (Collins 2022: 35), a key theme within a Black women’s standpoint as they navigate “intersecting oppressions of race, class, gender, sexuality, and nation” (Collins 2022: 28). In many ways, these artists represent part of a continuum of Black women’s resistance music (Collins 2022: 360).

YOUNG, GIFTED, AND BLACK

Patricia Hill Collins (2022) suggests that African American art forms, including blues, rhythm and blues, and progressive hip hop, are a significant “location where Black women have come to voice” (137). Tricia Rose (1994) similarly asserts that one of the predominant themes in the work of Black women rappers is “the importance of the female voice” (147). Rose notes that Black women rappers privilege “black female subjectivity and black female experiences in the public sphere,” providing “a means by which young black women can occupy public space in ways that affirm the centrality of their voices” (182). Gwendolyn Pough (2004) expands on the definition and theorization of “wreck” in hip hop, asserting that through hip hop culture itself “a generation of Black women is coming to voice and bringing wreck” as they attack “the stereotypes and misconceptions that influenced their lives and the lives of their foremothers” (87).

In the song “Lyte as a Rock,” MC Lyte (1988) describes the extent and dexterity of her skills as a rapper, emphasizing the significance of her voice. The song begins with her labelmate, Milk D, and her producer, King of Chill, introducing her and paying homage to her skills. MC Lyte opens by squaring off against anyone who attempts to shut her down and affirms that her words carry weight—“Must I say it again? I said it before/Move out the way when I’m coming through the door/Me, heavy? As Lyte as a Rock.” She makes it plain that she is only there to speak her mind—“If you hate rejection, don’t try to score/First base? You ain’t got what it takes.” She stresses her ability to leave the competition in the dust—“Chew em up, spit em out, just like popsicles.” More importantly, her emphasis is on her “stability, potential, and strength” as she describes the unequivocal depth of her skills, skills that overshadow all others—“If a rap can paint a thousand words, then I can paint a million.” She tells her listeners that she has faced obstacles—“I had a little trouble upon my arrival/But I got rid of those who tried to rock me/Lyte is here, no one can stop me.” Ultimately, she is a leader among many followers whose voice speaks to noteworthy knowledge bases—“There are hip hop leaders, this you know/We also have hip hoppers that follow/By the tone of my voice, you can tell I am a scholar/I’m also a leader of the hip hop followers.” She is regal in her stance and bearing, and she makes it clear who is in charge—“The grace as I ease across the stage/Bars around the audience, sort of like a cage/They laugh, cause they assume I’m in prison/But in reality, they’re locked in.” As Rose suggests, MC Lyte, and other women hip hop artists, attracted large male and female followings while they created and consistently performed “explicitly pro-women material in co-ed settings,” affirming “black female popular pleasure and public presence” (181-182).

R-E-S-P-E-C-T

Clover Hope (2021) suggests that women artists have been marginalized within hip hop from the beginning. She recounts how Roxanne Shanté, an early hip hop artist, lost a rap battle when Kurtis Blow, one of the first rappers to hit it big, “scored her low on purpose...because he didn’t like the optics of a girl winning a rap battle, no matter how much she outperformed her opponent” (4). Hope notes that this was an opening salvo that “shaped the course of history” as women in hip hop like Shanté found themselves facing “different stakes” and “a man’s world” within the business but also in the public sphere—“the mainstream press” found women’s “decision to even rap at all” to be “astonishing and brave” (4). Hope continues her vignette to the present noting that women hip hop artists still contend with barriers—a

top 50 rappers list podcast in 2019 “absent of any women” (5). But she also notes that that many women hip hop artists today are finally “controlling their image and art”—a coup that has been long in coming (6). Notably the literature also explores this constant refrain of sexism both within hip hop and in the public sphere but always tied to the specter of racism (Roberts 1991; Rose 1994; Phillips et al. 2005).

In the song “U.N.I.T.Y.,” Queen Latifah (1993) speaks to painful issues of sexual harassment, domestic violence, and the danger of gang life within Black communities, with an emphasis on healing rifts. In the first stanza, Queen Latifah starts out making it clear that there is no room for hateful speech between Black men and women—“Every time I hear a brother call a girl a bitch or a ho/Trying to make a sister feel low/You know all that gots to go.” Then she lays out an all too common tale of sexual harassment as she is simply walking down the block—“One day I was walking down the block/I had my cutoff shorts on right cause it was crazy hot/I walked past these dudes, when they passed me/One of ‘em felt my booty, he was nasty.” She is painfully aware of the violation of her person and faces the group in her anger—“I turned around red/somebody was catching the wrath” only to find the perpetrator lacks remorse—“Then the little one said ‘Yeah me bitch’ and laughed.” She underscores the need to call this out literally and physically—“Huh, I punched him dead in the eye/And said ‘Who you calling a bitch?’”

In the next stanza, Queen Latifah emphasizes that domestic violence is unacceptable no matter the cause—“Bad days at work give you an attitude/then you were rough/And take it out on me, but that’s enough.” She notes that she was blinded by the emotional bond—“I guess I fell so deeply in love/I grew dependent see”—but recognizes that this is hurting her children—“But I don’t want to see my kids see me getting beat down.” In the end, she leaves because she realizes that this is not the life she wants to live nor should anyone have to live this way—“You say I’m nothing without ya, but I’m nothing with ya/A man don’t really love you if he hits ya.” In the last stanza of the song, the focus is on the sorrow of watching a young woman lose herself to gang life—“What’s going on in your mind, is what I ask ya... You wear a rag around your head and call yourself a ‘gangsta bitch’ now.” The behavior of the young woman has escalated to “jumping girls after school,” which comes as a shock—“But where did all this come from?/A minute ago you was a nerd.” It is patently clear that she is trying to reach this young woman for many reasons not the least of which is to save her life—“There’s plenty of people out there with triggers ready to pull it/Why you try to jump in front of a bullet.”

Finally, the chorus that runs through these lessons and cautionary tales is a plea, a calling out, and a hope—“U.N.I.T.Y./U.N.I.T.Y that’s a

unity/U.N.I.T.Y love a black man from infinity to infinity (Who you calling bitch?)/U.N.I.T.Y./(You gotta let him know)/U.N.I.T.Y. that’s a unity/(Come on here we go) U.N.I.T.Y./(You gotta let him know)/love a black woman from infinity to infinity (You ain’t a bitch or a ho).” Ultimately, Queen Latifah is calling for honesty, integrity, and love between Black women and men—a road to understanding, enlightenment, and healing. Patricia Hill Collins (2022) speaks directly of Queen Latifah and her song “U.N.I.T.Y” as one of the few examples of Black women challenging Black men who accept prevailing notions of both Black and White masculinity” (199). Collins also asserts that “advising Black women to unquestioningly support sexual harassment, domestic violence, and other forms of sexism done by U.S. Black men buttresses a form of sexual politics that differently controls everyone” (198). At the same time, Collins similarly seeks healing and understanding as she writes, “Recognizing that corrupting and distorting basic feelings human beings have for one another lies at the heart of multiple systems of oppression opens up new possibilities for transformation and change” (222).

The song “Afeni” by Rapsody (2019) is named after Afeni Shakur, the former activist, Black Panther Party member, and mother of Tupac Shakur (Guy 2005). More than that, the artist actually weaves her lyrics around a chorus from Tupac Shakur’s classic work “Keep Ya Head Up” (1993), which submits a painful question—“I wonder why we take from our women, why we rape our women/Do we hate our women?” The first stanza is directed to Black men and starts out in a spirit of unity, not unlike Queen Latifah—“My brothers, I love you.” However, the next lines carry the anger she feels when some Black men abuse Black women and dismiss the beauty of Black women, additionally noting that this is based in lack of self-love—“teach your daughters all to stay away from suckas like yourself if you don’t love yourself.” Rapsody alludes to her background as a space of resilience and resistance to the abuse she describes—she was “taught to feed the soul with or without hot ovens,” an allusion perhaps to surviving and thriving with or without a romantic partner. More than that she offers Black men a plate of the food that feeds the soul and states that all the discouraging behavior by some Black men derives from the daily oppression Black men experience—“Here’s a plate, know your hate come from a Black man struggle.” She indicates that as a Black woman she knows the struggle all too well—“We all in the same shape, so I know I fit your puzzle.” The next line is quite tellingly supportive of all Black men enduring the shared struggle—“Either way, we got your back.” But she invokes a hope that Black men will reciprocate when Black women are experiencing intersecting oppressions—“We only pray you’ll be our muscle/Strength in the times

we all overcome with trouble.” She pleads for Black men to commit to having Black women’s back—“And I pray you feel the same way as that 2Pac song.” To this end, she states firmly that Black women will not submit to being pawns, tools, or objects—“We ain’t your hoes or your bitches, trophies, or meant for pimpin’.” She asks that Black men acknowledge the profound worth of Black women—“Recognize a gift from God outweighs a birthday or Christmas.” She then asks whether Black men will fully commit to this request, a willingness to literally defend and shield Black women from very real dangers—“To protect our lives, you gon’ take it to the limit?” Finally, she alludes to the biblical bond between women and men and wonders whether men can still recognize that bond—“Rib of my rib, do you still feel us in ya?”

The second stanza is addressed to Black women themselves, first acknowledging a history of painful struggle—“To my sisters, I know we on it/I feel your pain/I’m a woman disappointed.” The struggle she alludes to includes the brutality of rape—“They should never take what’s never given to ‘em ‘cause they want it.” The struggle also includes the abandonment of women with children—“I was taught, if you love me, you should never cut corners/What we made in the night, we got a raise in the mornin’.” More than that, she asserts that the struggle includes domestic violence as she again speaks directly to potential abusers—“you should never hit a woman.” She asserts that Black women and Black men should work in harmony and mentions the rapper Common as the model of a Black man who respects Black women—“We should have some things in common/Just like Common, he respect us.” Later in the stanza she invokes the loss of Tupac and how the genre still speaks to him—“2Pac gone, you know Rap had to message him.” She speaks to Afeni Shakur’s loss of her son and perhaps the loss of so many Black boys and men to so many Black mothers—“We tried to do our best for them, mother panther vibes.” This is followed by a call for the strength of Black men, and she suggests that the need of Black boys for their fathers is so profound that it can mean life or death—“We need strong men, so our baby boys survive.” She recognizes that living the struggle is not easy for anyone and that everyone is just human—“I know this life ain’t easy, every one of us is flawed.” But she asks that Black men “love your woman” because Black women are “the closest thing to God.” Perhaps Rapsody is simply stating that Black women survive so much of pain, disappointment, and trauma in the larger society as well as their own communities—so much racism, sexism, classism, and more—that their struggle has shaped extraordinary individuals who deserve to be revered. She closes by once again alluding to Tupac Shakur’s song—“And tell her to keep her head up, every day that it gets hard/If you truly recognize that.”

Patricia Hill Collins speaks in resonance with Rapsody's "Afeni" as Collins asserts that Black feminists explore the roots of Black male abuse of Black women, finding multiple sites of oppression.

Refusing to reduce Black men's abuse to individualistic, psychological flaws, Black feminist analyses are characterized by careful attention to how intersecting oppressions of race, gender, class, and sexuality provide the backdrop for Black heterosexual love relationships (204).

Moreover, Rapsody's work emerges as a site of what Collins describes as "generations in struggle" as she builds on the work of Afeni's son Tupac Shakur to create pathways of respect and understanding (386).

RIVER DEEP—MOUNTAIN HIGH

Angela Davis (1989) affirms the central role of music in African American culture, in that, "Black people were able to create with their music an aesthetic community of resistance, which in turn encouraged and nurtured a political community of active struggle for freedom" (201). Davis suggests that hip hop exists in a long line of resistance music from spirituals to the present—"a continuum of struggle which is at once aesthetic and political" (201). Resistance within the sociohistorical context of hip hop represents a shared angle of vision among Black women hip hop artists facing intersecting oppressions of, as Rose (1994) describes it, "social isolation, economic fragility, truncated communications media, and shrinking social service organizations" (33-34). This level of immiseration is only mirrored in Rose's later work as she describes "police targeting, racially motivated escalations of imprisonment, and reductions in support of what are still mostly segregated deeply unequal schools" (Rose 2008: 3).

The song "r(E)volution" by Sa-Roc (2020) summons a history of Black people in America through a formidable series of rhymes. The past and the present are called up together in a profoundly disturbing allusion to the sameness of this story whether told from the perspective of time now or time then. She starts by reminding her listeners of her skills—she has "Dropped from the clouds" like a goddess, and her rhymes come from a divine source—"Every word a work of art." Then the litany begins as she states that she is an "heir to an era of conflict" where the powerful rob from the poor and give to the rich in an endless prison industrial complex in a method that is the reverse of Robin Hood—"Professionals been robbin' hoods with a palm flick/Gave to the poor

and the Black the stigmata of convict.” She notes that this “cross,” a Christian allusion, has been a longstanding one to bear in a country that locks up disenfranchised Black people—“Embedded in the home of the brave, the darkest of interiors.” She has witnessed Black people giving in to the system or perhaps being lost in the system, because they could no longer bear the cross of systemic racism—“Saw street scholars and soldiers defect/‘Cause they post-traumatic stressed from the American experience.” She looks back to her origin story to unpack the history of enslavement—“See my heart bleed from the hardship in my origins/My great grand sold for a band at Southern auctions.” This history cuts deep, a history she has researched at length and a history that has sharpened her tongue—“It’s the razor edge in my cadence that shredded these paper trails.” She notes that the only “alphabet boys I trust are NOI and Els”—a reference to the Nation of Islam (Felber 2020). She is fighting the forces that “lynch” her people whether literally or figuratively as she invokes the name of an anti-lynching activist—“trying to be the next Ida Wells” (Wells-Barnett 1895).

The second stanza is just as dense, with Sa-Roc once again reminding her listener that she rules “over every subject and predicate” in her rhymes. She wants the world to know of these injustices—“Scrawl these searing indictments on every edifice.” She asks to be excused for the “venom in my rap voice,” but she wants us all to know there is a reason for it—“‘Cause more often than sweet, life served vinegar in Black homes.” The biting lyrics in this verse are specifically about the crack epidemic in disenfranchised Black neighborhoods and mass incarceration that followed—“More specifically where fire lit them crack stones/War on drugs turned a fiend to a felon in a snap, gone.” She asserts that “polished liars”—perhaps scholars—are “trying to tell us that Shabazz is a dying tribe,” that African Americans are dying out (Felber 2020). So, she has decided to “turn this pen and tablet to a tabernacle”—into a seat of worship as she is indistinguishable from “God,” that is “I and I”—a reference to Rastafarian belief that signifies “oneness between two (or more) persons and between the speaker and God” (Bedasse 2017: 207). She will spit “the twelve jewels” to “free ‘em from the thirteenth”—a reference to the “Twelve Jewels of Islam” perhaps to be freed from the 13 colonies of the U.S. (Felber 2020). But more than anything she is clear that Black people will not continue to be colonized—“They can’t buy the spirit of our nation, cut the purse strings.” She declares that Black people are recovering the “Ghanaian gold”—perhaps the gold itself, but more importantly the legacy of the people taken from the Gold Coast of Ghana to be enslaved in America (Shumway and Getz 2017). She notes that Black people are “Buying back the blocks/Black Wall Street pursuit”—reestablishing the legacy of

Black Wall Street that was destroyed in Tulsa, Oklahoma in 1921 (Madigan 2003). It has been a difficult journey, but the people will prevail—“If we fell couple of times, the rise absolute, trust me.”

The chorus of the song is a call and an invocation, but also a strident rebuke of a range of inequity that has been the history of Black people in America—from enslavement, to Jim Crow, to all manner of intersecting levels of oppression. Sa-Roc speaks directly to Black people, stating that whatever the dominant narrative may spout, Black people are here in this country to stay and to thrive. She also suggests that a battle may have to be joined in the streets—perhaps a reference to #BlackLivesMatter protests in major cities. Further, she suggests that the powers that be want to hold Black people down—keep them in “their place.” But her response to this systemic racism, classism, and sexism is to suggest that real change will only happen when the people rise up and make change themselves.

I don't know what you might've heard
 But we ain't going nowhere but up
 Got a whole squad dressed in all black
 Got the streets on notice, what up?
 They want us in the same place
 Ain't nobody ever gonna really change nothing but us
 Hello, this is revolution, get on up

In a discussion of Black women's activism, Patricia Hill Collins suggests that African American “women craft Black female spheres of influence that resist oppressive structures by undermining them” (260). More than this, Collins states that Black women embrace “a worldview that sees lived Black experiences as important to creating a critical Black consciousness and crafting political strategies” (260). Just so, Sa-Roc articulates her own history within a larger African American history as she crafts stories of lived experiences in the struggle for movement and empowerment.

CONCLUSION

This analysis has focused on the work of four women hip hop artists from very distinct historical timeframes—MC Lyte and Queen Latifah came to voice in the 1980s, while Rapsody and Sa-Roc are making their mark on our contemporary era. Each artist speaks to issues facing Black women in their time with resonance to specific themes—coming to voice, ongoing issues with sexism laced with racism, but moreover overarching and intersecting levels of oppression within the larger

society. In addition, our four women hip hop artists are unequivocal in their oppositional stance as they forge “dignity and autonomy” while offering “insightful critiques of the dominant group” (Mitchell and Feagin 1995: 68, 69). More than that, our artists speak to intersecting oppressions in the lives of Black women, articulating aspects of “Black feminist thought” as a legacy of struggle and a core theme of Black women’s standpoint.

In the 30th anniversary edition of what is arguably her magnum opus, *Black Feminist Thought: Knowledge, Consciousness, and the Politics of Empowerment*, Patricia Hill Collins (2022) writes of “intergenerational hope,” each generation fighting in the struggle for so many aspects of what are really human rights—social justice, freedom, equity, peace—and preparing “a space for new generations to fly” (386). While entrenched in the continuing fight, she talks of moments of profound strain—“when you think you cannot take one more step”—and how something as simple as “a meal that nourishes your body or a song that moves your soul” can alter everything (387). Your savior who offers the meal or song, Collins writes, comes in many guises but

She is unapologetically Black, female, visible, and vocal. She leads you by imagining the future that she needs to build. She is the one who embodies hope from one generation to the next. She is one of the many that we have been waiting for. (387)

The deliberate, thoughtful, courageous work of our four selected hip hop artists—MC Lyte, Queen Latifah, Rapsody, and Sa-Roc—moves the soul, embodying hope and a legacy of struggle from generation to generation.

ACKNOWLEDGMENTS

Many thanks to Patricia Hill Collins, Joe Feagin, and Bonnie Mitchell for the wealth of their ideas. Thanks also to Brett Clark for his always thoughtful and substantive support of my research. Sincere thanks go to the many women hip hop artists who continue to challenge barriers to social justice in their time.

REFERENCES

Bedasse, Monique A. 2017. *Jah Kingdom: Rastafarians, Tanzania, and Pan-Africanism in the Age of Decolonization*. Chapel Hill, NC: The University of North Carolina Press.

Collins, Patricia Hill. 2022. *Black Feminist Thought: Knowledge, Consciousness, and the Politics of Empowerment*, 30th Anniversary Edition. New York: Routledge.

Davis, Angela Y. 1989. *Women, Culture & Politics*. New York: Random House.

Felber, Garrett. 2020. *Those Who Know Don't Say: The Nation of Islam, the Black Freedom Movement, and the Carceral State*. Chapel Hill, NC: The University of North Carolina Press.

Feldman, Ella. 2022, September 22. "Sa-Roc carries the torch of Chocolate City Forward." Retrieved January 23, 2023, from <https://washingtoncitypaper.com/article/572636/sa-roc-carries-the-torch-of-chocolate-city-forward/>.

Guy, Jasmine. 2005. *Afeni Shakur: Evolution of a Revolutionary*. New York: Atria.

Hope, Clover. 2021. *The Motherlode: 100+ Women Who Made Hip-Hop*. New York: Abrams Image.

Keyes, Cheryl L. 2000. "Empowering self, making choices, creating spaces: black female identity via rap music performance." *Journal of American Folklore* 113(449): 255-269.

Lofland, John and Lyn H. Lofland. 1995. *Analyzing Social Settings: A Guide to Qualitative Observation and Analysis*. 3rd ed. Belmont, CA: Wadsworth.

Madigan, Tim. 2003. *The Burning: The Tulsa Race Massacre of 1921*. New York: St. Martin's Griffin.

Mitchell, Bonnie L. and Joe R. Feagin. 1995. "America's racial-ethnic cultures: opposition within a mythical melting pot." In *Toward the Multicultural University*, edited by B. Bowser, T. Jones and G.A. Young, pp. 65-86. Westport, CT: Praeger.

Morgan, Joan. 1999. *When Chickenheads Come Home to Roost: My Life as A Hip Hop Feminist*. New York: Simon & Schuster.

Pearce, Sheldon. 2019, August 27. "Rapsody: Eve Album Review." *Pitchfork*. Retrieved February 5, 2023, from <https://pitchfork.com/>

reviews/albums/rapsody-eve.

Phillips, Layli, Reddick-Morgan, Kerri and Dionne Patricia Stephens. 2005. "Oppositional consciousness within an oppositional realm: the case of feminism and womanism in rap and hip hop, 1976-2004." *Journal of African American History* 90(3): 253-277.

Pough, Gwendolyn. 2004. *Check it While I Wreck it: Black Womanhood, Hip-Hop Culture, and the Public Sphere*. Boston: Northeastern University Press.

Reinharz, Shulamit. 1992. *Feminist Methods in Social Research*. New York: Oxford University Press.

Roberts, Robin. 1991. "Music videos, performance and resistance: feminist rappers." *Journal of Popular Culture* 25(2): 141-152.

Rose, Tricia. 1994. *Black Noise: Rap Music and Black Culture in Contemporary America*. Hanover, NH: Wesleyan University Press

_____. 2008. *The Hip Hop Wars*. New York: Basic Books.

Shumway, Rebecca and Trevor R. Getz. 2017. *Slavery and its Legacy in Ghana and the Diaspora*. London: Bloomsbury Academic.

Wells-Barnett, Ida B. 1895. "The Red Record: Tabulated Statistics and Alleged Causes of Lynching in the United States." Chicago: Donohue & Henneberry.

MUSIC REFERENCES

MC Lyte. 1988. "Lyte as a Rock." *Lyte as a Rock*. First Priority, Atlantic.

Queen Latifah. 1993. "U.N.I.T.Y." *Black Reign*. Tommy Boy.

Rapsody. 2019. "Afeni." *Eve*. Jamla, Roc Nation.

Sa-Roc. 2020. "r(E)volution." *The Sharecroppers Daughter*. Rhymesayers Entertainment.

Shakur, Tupac. 1993. "Keep Ya Head Up." *Strictly 4 My N.I.G.G.A.Z.* Interscope, Jive.

Women, Weight, and the Workplace: Exploring the Effects of Economic Weight Bias Against Women

Niko Dawson

Weber State University

Abstract

Extensive effort has gone into researching the gender pay gap and what forces could be responsible for this societal disadvantage. Meanwhile, studies have shown an overall negative relationship between income and weight, concluding that obesity rates are higher at lower levels of income. Despite the apparent connection between income and weight, less research has been conducted to analyze the likelihood that the causality runs in the reverse direction: perhaps weight bias at the workplace causes lower income among heavier people. Using the most recent quantitative data from the National Health and Nutrition Examination Survey, this research uses an interval regression model of income on weight with additional control variables to examine the effect of weight bias on income for men and women. This analysis found that women are receiving lower incomes for weighing more, while the opposite is true for men. On average, each additional pound women weigh was correlated with a loss of household income of \$3.21 per month ($p < 0.01$), implying weight-based discrimination against women.

Introduction

Women experience different treatment than men do at their place of work. They are less likely to be promoted, remain the minority in executive positions, and receive less money for the same positions than men with similar experience hold (Castaño et al., 2019; Meara et al., 2019), all of which contribute to the gender pay gap. Considerable effort has tried to pin down the societal influences responsible for the pay disparity between men and women, and there is a general consensus that it is not a single variable but rather multiple factors that are contributing to wage inequality (Bolotnyy & Emanuel, 2022; Litman et al., 2020). Whereas a lot of research has analyzed the effect that income has on weight, concluding that lower income results in higher chances of obesity (Ameye & Swinnen, 2019; Drewnowski, 2009), a significantly smaller portion of research has focused on the likelihood that weight bias at the workplace causes this relationship to be significant when reversed. Through this lens, it can be argued that lower income for women is being perpetuated by weight bias in the workplace. Research has found that both your chances of being hired and your wage are affected by your appearance, a phenomenon that is referred to as the ‘beauty premium’ (Li et al., 2023). Social media, advertisements, the fashion industry, and others have all contributed to the idea that weighing more is an unattractive quality, especially for women (Fardouly & Vartanian, 2016). These have all exacerbated the many difficulties heavier women face, including bullying, dehumanization, and discrimination in health care (Kersbergen & Robinson, 2019, Talumaa et al., 2022). Based on this evidence, weight could be one aspect contributing to the gender pay gap, acting as a sort of subsection of the ‘beauty premium’ issue.

Previous literature has shown conflicting results when it comes to the effect that weight has on income. It has been shown that this relationship can depend on industry, region, and race of individuals surveyed (Shinall 2014). In most cases, research found a negative relationship between income and weight for women, and no relationship or some positive correlation between income and weight for men. In one study, the results among women remained consistent with the aforementioned literature, but the investigators found a negative relationship between income and weight for men as well, at least once weight was categorized as obese (Dor et al 2011). In others, the negative effects of weight on income grew as weight increased (Shinall 2014). Additionally, results differed based on world region and on reported ethnicity, particularly when looking at developed versus developing countries (Mathieu-Bolh 2021). Existing literature on this topic is already sparse, and most studies were done in other countries such as

Korea or Finland (Kim & Knesebeck, 2018; Sarlio-Lähteenkorva et al., 2004). Otherwise, the research was done on a collection of studies that included the US as well as other countries like Canada and the United Kingdom (Judge & Cable, 2011; Kim & Knesebeck, 2018). Even the website of the National Institutes of Health, a part of the US government, cites an article that studies the impact of weight on income for Korean high school students, which is a vastly different demographic from the residents of the US (Lee et al., 2019). The US has one of the highest obesity rates in the world, and 78% of adults in this country are projected to be overweight by 2030 (Wang et al., 2020). Because of this unique demographic, it is important to study the impact of weight on solely US residents to get the clearest idea of how weight is affecting the gender pay gap in the country.

Using the most recent quantitative data from the US National Health and Nutrition Examination Survey (NHANES), this paper uses separate interval regression models to dissect the effect that income has on weight for men and women in the United States. Moreover, this paper will discuss the consequences of this relationship and how it fits into the overarching issue of the gender pay gap, in addition to adding support to and filling in regional gaps in existing literature.

Econometric Model

This paper focuses on quantifying the effects of weight on income for women in the US using basic econometric analysis. The simple regression model used is shown below:

$$y_i = \beta_0 + \beta_1 W_i + \beta_2 X_i + u_i$$

where y is the dependent variable of interest, annual household income. The main explanatory variable (W) represents weight of the participants at the time of the survey, measured in pounds. X represents the remaining control variables and explanatory variables of interest, such as height, age, physical activity, smoking habits, alcohol consumption, race, marital status, hours worked, and education level, each of which was chosen by careful observation of existing literature, the scope of the data set, and possible relation to the dependent variable. The variable u represents unobserved variables. A short description of each explanatory variable used in the regression model can be found in Table 1. The variable y is estimated through a special technique of regression known as interval regression, because of the nature of how data on income were collected. Using interval regression analysis allows us to examine data where the exact value is not known but instead resides in a range of specified values. Additionally, it allows the usage of data where an upper

or lower range does not exist, in this case reported income above \$100,000, using advanced techniques to more accurately predict the estimators than ordinary least squares regression.

Table 1. Variable descriptions	
<i>monthinc</i>	total monthly household income
<i>weightlbs</i>	weight of respondent at time of survey (in pounds)
<i>white</i>	=1 if respondent is Non-hispanic White, 0 otherwise
<i>black</i>	= 1 if respondent is Black, 0 otherwise
<i>asian</i>	= 1 if respondent is Asian, 0 otherwise
<i>hispanic</i>	= 1 if respondent is Hispanic, 0 otherwise
<i>lesshsdiploma</i>	= 1 if respondent's highest education level is less than a highschool diploma, 0 otherwise
<i>college</i>	= 1 if respondent's highest education level is a four-year college degree or above, 0 otherwise
<i>marr</i>	= 1 if respondent is married, 0 otherwise
<i>divorced</i>	= 1 if respondent is divorced, 0 otherwise
<i>physact</i>	amount of moderate level physical activity per day (in minutes)
<i>smoke</i>	average number of cigarettes smoked daily
<i>alcohol</i>	average number of drinks daily
<i>hrswork</i>	amount worked per week (in hours)
<i>age</i>	age of respondent at time of survey
<i>heightin</i>	height of respondent at time of survey (in inches)

Some bias may enter this model by means of a lower response rate (about 50%) and through self-reporting errors that are typical with surveys, particularly ones questioning household income. Bias may also occur through omission of important variables that are not available or impossible to be collected. In this case, bias might occur through incomplete surveying of overall health level or physical activity, both of which can affect both weight and income. Additionally, excluding variables such as household size, body mass index (BMI), or level of perceived attractiveness may also cause bias, and these should be controlled for in future research if possible. However, this particular data set reduces the chance of bias through a well-collected survey, sampling individuals from all US counties and increasing the number of screenings for certain subgroups, such as specific races and low-income households, that tended to have lower response rates in previous years' surveys. Using interval regression can cause issues if the assumption of normality is violated. Fortunately, the sample size is large enough to assume normality, and the regressions are run with robust standard errors, producing standard errors that are robust to heteroskedasticity.

Data

The data used for the regression model are collected from the most recent NHANES that was uninterrupted by the Covid-19 pandemic, taken in 2017-2018. The NHANES survey is typically conducted on a biyearly basis by the US Center for Disease Control and Prevention (CDC) and is a national survey that can control across regions and time. Every year, they select upwards of 10,000 participants to be interviewed in their home and then instruct them to complete a health examination nearby. These participants are selected through a computer randomized process, in which households are interviewed and a random number of the household members are selected to complete the entire NHANES survey. For the 2017-2018 survey, 16,211 people were selected, and 8,704 people were both interviewed and completed the health examination. These responses are then compiled into several data sets categorized by demographics, dietary data, examination data, and data received from the interviews, which are sorted by identification numbers that follow individuals across each data set.

Income is collected during the interview portion and is reported as annual household income through interval data starting at 0 to over \$100,000 a year. A crucial downside to using the NHANES 2017 data set is the fact that income is recorded by household, not for each individual, but there are several steps taken to produce the estimated effects for individuals rather than households. Weight, the main explanatory variable of interest, was collected at the health examination in kilograms, although for the sake of easier interpretation, it has been converted into pounds for the regression. The inclusion of this variable and other health examination variables like height results in some nonresponse bias that occurred when those who participated in the interview did not show up to the designated location for the examination. Data collected for this study include only the observations for men and women 20 years or older, which is acceptable for the purpose of analyzing income.

The NHANES data set lists the variable they collected as ‘gender’ but does not include options other than male or female for the participants to choose from. The inclusion of trans and nonbinary individuals in this survey was not made evident by the questionnaire that NHANES conducted. Because of the lack of information about gender identity and the fact that this is primarily a health survey, it can be assumed that the variable that is listed as ‘gender’ is more associated with the participants’ biological sex. For the sake of continuity, I use the more inaccurate term ‘gender’ throughout this paper but recognize that this term is not consistent with what is being described.

Table 2 presents the descriptive statistics (mean and standard deviation) of each of the explanatory variables included in the model, as well as those dropped for the regressions. Also included is the independent variable of household income reported on the entire sample and each separate gender. Because income was reported in intervals, the mean monthly income does not have any consequential interpretation. The precise maximum income is also unknown (reported as \$100,000 or more) for approximately 270 respondents of each gender, resulting in some right-censored data that interval regression is equipped to handle. The demographics for age, race, and education level remained very similar across genders, but women in this data set reported being single at higher rates than the men.

Table 2. Descriptive statistics

Dependent Variables	All		Women		Men	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
<i>monthinc</i>	3176.68	1998.03	3121.12	1982.91	3237.07	2013.17
<i>weightlbs</i>	183.06	50.67	171.00	49.80	196.00	48.36
<i>white/non-hispanic</i>	0.38	0.49	0.37	0.48	0.39	0.49
<i>black</i>	0.23	0.49	0.23	0.42	0.22	0.41
<i>asian</i>	0.14	0.38	0.15	0.35	0.13	0.34
<i>hispanic</i>	0.12	0.32	0.12	0.32	0.12	0.32
<i>otherrace</i>	0.14	0.34	0.13	0.34	0.14	0.38
<i>lessshdiploma</i>	0.07	0.26	0.06	0.25	0.08	0.26
<i>hsdiplomaorsomecollege</i>	0.68	0.47	0.68	0.46	0.68	0.47
<i>college</i>	0.25	0.43	0.25	0.43	0.25	0.43
<i>divorced</i>	0.12	0.32	0.13	0.33	0.11	0.31
<i>marr</i>	0.51	0.50	0.46	0.50	0.55	0.50
<i>singleorother</i>	0.38	0.48	0.41	0.49	0.34	0.47
<i>physact</i>	24.78	46.11	20.88	37.16	28.96	53.79
<i>smoke</i>	2.09	5.68	1.60	4.81	2.62	6.44
<i>alcohol</i>	1.61	2.05	1.27	1.54	1.97	2.43
<i>hrswork</i>	21.35	22.23	18.71	21.06	24.18	23.08
<i>age</i>	51.23	17.58	50.63	17.54	51.87	17.60
<i>heightin</i>	65.46	4.67	62.91	3.38	68.20	4.28
<i>n</i>	4,156		2,151		2005	

Empirical Results

The descriptive data presented in Figures 1 and 2 show the average household monthly income by weight quartile for men and women. The figures show a linear negative trend between income and weight for women and an exponential positive relationship for men, decreasing slightly once reaching the fourth quartile. These results are similar to those produced by the regression analysis (results shown in Table 3).

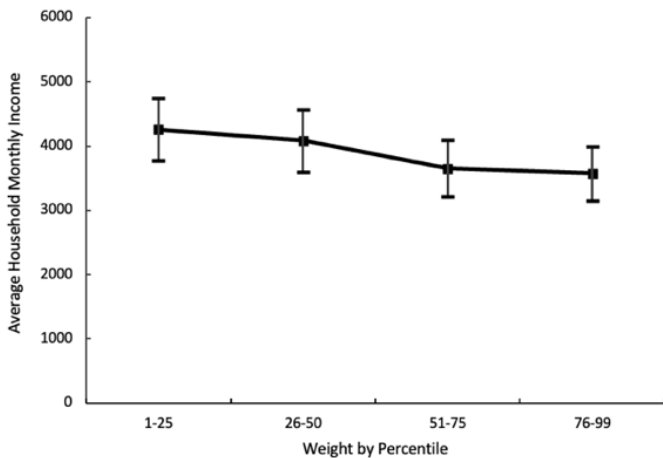


Figure 1. Women’s average household income grouped by quartile.

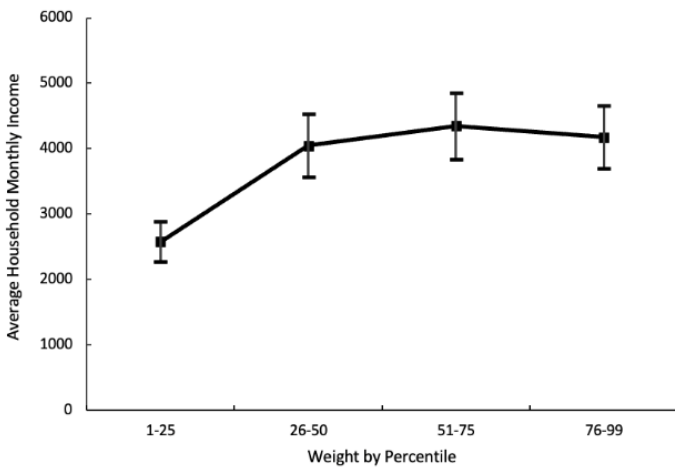


Figure 2. Men’s average household income grouped by quartile.

Table 3. Regressions of monthly family income on weight

Variables	Women		Men		Single Women	Single Men
	(1)	(2)	(3)	(4)	(5)	(6)
<i>weightlbs</i>	-3.208** (1.130)	-6.166 (4.885)	.658 (1.236)	21.357*** (6.205)	-3.066* (1.439)	20.417** (7.589)
<i>weightlbs</i> ²	-	-	-	-.046** (.013)	-	-.045** (.016)
<i>black</i>	-256.946* (128.627)	-255.064* (128.728)	44.863 (142.985)	60.425 (142.775)	-237.698 (153.590)	122.682 (194.017)
<i>asian</i>	496.852* (201.991)	483.581* (203.711)	680.990** (220.703)	731.761*** (220.924)	1457.109*** (373.372)	1605.305*** (462.662)
<i>hispanic</i>	15.744 (175.911)	19.668 (175.803)	69.506 (191.950)	10.391 (193.784)	-132.039 (245.744)	162.183 (305.976)
<i>lesshsdiploma</i>	-803.152*** (201.245)	-799.471*** (200.987)	-1179.303*** (181.368)	-1149.808*** (181.306)	-237.478 (307.146)	-665.008 (330.963)
<i>college</i>	1921.922*** (144.861)	1921.540*** (144.940)	1876.910*** (165.139)	1856.745*** (165.243)	1438.720*** (194.029)	1012.490*** (256.020)
<i>marr</i>	1550.947*** (120.834)	1552.449*** (120.862)	1212.064*** (134.087)	1190.137*** (133.961)	-	-
<i>divorced</i>	-551.977*** (149.120)	-551.638*** (148.996)	-429.062*** (165.201)	-437.869*** (164.767)	-	-
<i>physact</i>	2.819* (1.369)	2.836* (1.371)	3.185** (1.153)	3.133** (1.150)	1.253 (1.704)	1.488 (2.037)
<i>smoke</i>	-53.484*** (9.681)	-53.627*** (9.704)	-51.261*** (7.230)	-48.613*** (7.280)	-49.027*** (10.265)	-31.285** (10.874)
<i>alcohol</i>	79.453* (34.876)	80.348* (34.919)	2.577 (23.833)	- .658 (23.720)	16.428 (39.834)	-19.162 (31.635)
<i>hrswork</i>	22.022*** (2.785)	22.098*** (2.785)	27.948*** (3.054)	27.522*** (3.049)	18.682*** (3.875)	20.877*** (4.750)
<i>age</i>	8.121* (3.497)	8.281* (3.494)	6.379 (4.278)	5.365 (4.283)	-1.827 (4.907)	-14.703** (5.757)
<i>heightin</i>	-65.963 (41.063)	-67.079 (41.267)	-142.500** (50.555)	-134.429** (50.293)	-76.705* (31.573)	-90.938 (87.860)
<i>heightin</i> ²	.932* (.440)	.947* (.441)	1.604*** (.463)	1.457** (.462)	.825* (.470)	.546 (.785)
<i>_cons</i>	2946.137** (1139.705)	3222.222** (1243.147)	4141.860* (1624.760)	2165.936 (1699.003)	4541.679*** (548.961)	4720.380 (2902.517)
Correlation						
ML(Cox-Snell) R2:	0.295	0.295	0.306	0.309	0.185	0.198
Robust standard errors in parentheses						
* p<0.05, ** p<0.01, *** p<0.001						

Table 3 summarizes the results of six interval regressions of household income on the main independent variable weight, along with additional explanatory variables for race, education, marriage status, physical activity, smoking habits, alcohol consumption, hours worked, age, and height. Because interval regression does not give either R-squared or pseudo-R-squared, the Cox-Snell R-squared is included at the bottom of each regression as a measure of goodness-of-fit. After controlling for these background variables, weight remains both statistically and practically significant for both men and women, although the results for each gender differ.

For women, the regression including just *weightlbs* (Regression 1) was more significant than the one including an additional variable for weight squared (Regression 2), meaning that the effect that weight has on income for women is a linear one and remains constant on average across all weights. Each additional pound women weigh correlated with

a loss of household income of \$3.21 per month on average, holding the other control variables constant. The true impact of this number is a lot easier to see at higher weights. A woman weighing in the 75th percentile (195.58 lbs.), or around 25 pounds more than the average weight for women in the sample, earns on average \$79 less a month, or about \$947 less a year, than a woman of average weight. A woman in the 95th percentile (269.76 lbs.), has a household income that is \$317 a month (\$3,804 per year) less than her average-weighting counterpart. The significance of this relationship suggests the existence of some form of economic weight bias against women in the workplace.

To begin examining this relationship, we first must compare these results against the results of the regression for men. Controlling for the same variables, you get different results on the relationship between weight and income. First, instead of a negative relationship like with women, the relationship between income and weight for men is actually positive. Unlike the regression for women, the linear relationship between weight and income (Regression 3) is significant at the 10% level, but not the 5% level. Instead, the relationship becomes significant when you add a variable for weight squared (Regression 4), meaning the relationship is parabolic, at this point being significant even at the 1% level. For each additional pound they weigh, men earned a higher income on average. Because the shape of this relationship is parabolic, at a certain point it becomes negative, but this point is outside of the data set (around 490 pounds), meaning it cannot be interpreted for our purposes. Instead, this parabolic relationship shows that the additional income per pound is continuously increasing on average for men throughout the observed weights in the data set but has different effects at different weights. At the average weight for men in the data set (196 lbs.), an additional pound earns an additional \$12.34 per month on average, with all else constant. This relationship slows down as weight increases, so at the 75th percentile for men (222 lbs.), they are only earning an additional \$11.15 per month for each marginal pound weighed. The effect continues to diminish up until 490 pounds, at which point it is predicted to become negative, although the highest recorded weight for men in this sample is 436 pounds, meaning there is no significance to this vertex.

For both men and women, the effect of physical activity on income was very similar: for each additional minute of physical activity per day, income per month increases on average by \$3, meaning just exercising one extra hour per day increases monthly income by \$180 when holding all else constant. This is an interesting addition to the previous discussion. If it is true that a societal beauty standard is having some effect on income, then additional weight for women and men means different things. It could be that in most cases, additional weight for men

means more muscle mass, drawing closer to a standard of attractiveness, which would be a possible explanation for the nonlinear relationship of income and weight seen for the men in this data set. At higher levels of weight for men, this additional weight is less likely to be due to an increase in muscularity. For women, the beauty standard is not strength, explaining the negative effect on income with extra weight gained. To test this hypothesis further, data would need to be collected on BMI for each respondent as well, although this suggestion is hesitant because of the problems with the measurement of BMI (Rothman, 2008; Sugiura & Murata, 2010). This relationship shows one possible way weight bias is actively contributing to the gender pay gap.

Although the survey collected data on household income, there are several reasons that the effect of weight on income remains significantly different based on whether the household respondent was female or male. First, men could be earning more with increased weight because of psychological biases. One study found that, for men, being overweight increased perceived persuasiveness and confidence, whereas it decreased those perceived traits in women (Kniffin et al., 2019). The level of confidence and persuasiveness translates directly to income, as people with those traits will be given more authority and responsibility, effectively increasing their income. A second possible explanation could be that there was a larger proportion of single female respondents than male respondents. Just over half of female respondents, 53.79%, reported their marital status as something other than married. Additional household income might be present even if the respondent is not married, but for the most part these female respondents will have a single household income. For those that are married, the additional income is controlled for in the regression with the variable *marr*. Another control method was used by running a regression on just the respondents that reported their marital status as divorced, widowed, separated, or never married, excluding those that reported being married or living with a partner. For women, this new regression did not include the *weightsq* variable so it could be compared with the most significant regression run for all women. These results are shown in the last two columns of the regression analysis (Table 3). Interestingly, the effect of weight on income remained almost exactly the same for both men and women as in the regression that included those that were married, with minimal changes to the effect of the control variables as well.

Several possible explanations exist for why the results of Regressions 1 and 4 are similar to those produced for the single respondents. If women were the ones responding, we know their reported weight, but we do not know anything about the weight of other household members, including another spouse or roommate bringing in

income. It could be that people who weigh more either work fewer hours or have higher rates of unemployment, meaning the household income would be largely generated by a single person. Otherwise, weighing more is associated with lower rates of cohabiting with a partner (Campbell et al., 2021), which could also be a contributing factor to this phenomenon. Both of these explanations would need to be confirmed through further research, but they could both reasonably explain why a relationship you would expect to see on an individual level is still occurring on a household level.

This statistical analysis was not able to completely disregard the possibility of reverse causality, but a strong argument can be made for the possibility that both relationships exist simultaneously. Although it has been found that lower income can lead to obesity (e.g., Mobley et al., 2006), we cannot overlook the possibility that the relationship may go the other way as well. Because the results are so different for men and women, it seems to be unlikely that the relationship only goes in one direction. Lower-income households will typically consume the same foods, both in type and amount, meaning that the relationship of weight and income should be relatively similar across genders, and it would not result in such different outcomes for men and women.

Conclusion and Further Research

Women are receiving lower incomes for weighing more, whereas the opposite is true for men. These results coincide with previous research on the beauty premium in labor markets, a recorded trend where more attractive people receive higher income on average. One study found that there is a wage premium for both attractive men and women (Doorley & Sierminska 2012). Higher weights for women are typically seen as unattractive in societal standards, leading to lower income, which would match the results of the regression analysis in this paper. If this is true, then prejudice is seeping into income, negatively impacting women. There are several reasons why this implication could be harmful. First, if lower income also increases likelihood of obesity, these two relationships could lead to a spiral that is difficult to escape; higher weight leads to lower income, which leads to even higher weight, and so on. Additionally, the results of this regression analysis show a deeper look into one aspect of the gender pay gap and overall income discrimination.

Because of the limitations of the NHANES data set, this project could benefit from further analysis. Some further research to consider includes collecting noninterval data on income, individual income, and variables for both region and industry. Specifically, controlling for

industry could provide a vastly different outcome in the effect of weight on income because of the differences between male- and female-dominated fields. However, even if this were the case, a difference in jobs and therefore income based on weight would still be the result of institutional bias against heavier women, which would not change the general societal implication that this research tries to address. Additionally, it would be interesting to see further research on the psychological biases of perceived confidence and how this affects income for each gender. Further examination of prejudice in income, whether discrimination is based on beauty, gender, weight, or some combination of the three, is important to continuously examine, because these prejudices have harsh real-life implications for people every day.

Acknowledgments

Thank you to my mentor on this project, Dr. Brandon Koford, and to the Office of Undergraduate Research at Weber State University, which provided me with many opportunities to present and polish this research. I would also like to thank Dr. Jennifer Gnagey and Dr. Therese Cavlovic because this paper would not have been possible without their help and guidance.

References

- Ameye, H., & Swinnen, J. (2019). Obesity, income and gender: The changing global relationship. *Global Food Security*, 23, 267–281. <https://doi.org/10.1016/j.gfs.2019.09.003>
- Bolotnyy, V., & Emanuel, N. (2022). Why do women earn less than men? Evidence from bus and train operators. *Journal of Labor Economics*, 40(2), 283–323. <https://doi.org/10.1086/715835>
- Campbell, D.D., Green, M., Davies, N., Demou, E., Ward, J., Howe, L. D., Harrison, S., Johnston, K.J., Strawbridge, R.J., Popham, F., Smith, D.J., Munafò, M.R., & Katikireddi, S.V. (2021). Effects of increased body mass index on employment status: A mendelian randomisation study. *International Journal of Obesity*, 45(8), 1790–1801. <https://doi.org/10.1038/s41366-021-00846-x>

Castaño, A., Fontanil, Y., & García-Izquierdo, A. (2019). “Why can’t I become a manager?” A systematic review of gender stereotypes and organizational discrimination. *International Journal of Environmental Research and Public Health*, *16*(10), 1813. <https://doi.org/10.3390/ijerph16101813>

Centers for Disease Control and Prevention. (2022, November 29). *NHANES—National Health and Nutrition Examination Survey homepage*. Centers for Disease Control and Prevention. Retrieved November 29, 2022, from <https://www.cdc.gov/nchs/nhanes/index.htm>.

Doorley, K., & Sierminska, E. (2012). Myth or fact? The beauty premium across the wage distribution. IZA Discussion Paper No. 6674. <https://doi.org/10.2139/ssrn.2101941>

Dor, A., Ferguson, C., Tan, E., Divine, L., & Palmer, J. (2011, November 17). *Gender and race wage gaps attributable to obesity*. Washington, D.C.: Department of Health Policy, School of Public Health and Health Services, The George Washington University. Retrieved November 29, 2022 from https://hsrc.himmelfarb.gwu.edu/sphhs_policy_facpubs/230/

Drewnowski, A. (2009). Obesity, diets, and social inequalities. *Nutrition Reviews*, *67*(suppl 1), S36–S39. <https://doi.org/10.1111/j.1753-4887.2009.00157.x>

Fardouly, J., & Vartanian, L.R. (2016). Social media and body image concerns: Current research and future directions. *Current Opinion in Psychology*, *9*, 1–5. <https://doi.org/10.1016/j.copsyc.2015.09.005>

Judge, T.A., & Cable, D.M. (2011). When it comes to pay, do the thin win? The effect of weight on pay for men and women. *Journal of Applied Psychology*, *96*(1), 95–112. <https://doi.org/10.1037/a0020860>

Kersbergen, I., & Robinson, E. (2019). Blatant dehumanization of people with obesity. *Obesity*, *27*(6), 1005–1012. <https://doi.org/10.1002/oby.22460>

Kim, T.J., & von dem Knesebeck, O. (2018). Income and obesity: What is the direction of the relationship? A systematic review and meta-analysis. *BMJ Open*, *8*, e019862. <https://bmjopen.bmj.com/content/8/1/e019862>

Kniffin, K.M., Bogan, V.L., & Just, D.R. (2019). “Big men” in the office: The gender-specific influence of weight upon persuasiveness. *PloS One*, *14*(11), e0222761. <https://doi.org/10.1371/journal.pone.0222761>

Lee, H., Ahn, R., Kim, T.H., & Han, E. (2019). Impact of obesity on employment and wages among young adults: Observational study with panel data. *International Journal of Environmental Research and Public Health*, *16*(1), 139. <https://doi.org/10.3390/ijerph16010139>

Li, L., Chiu, D.K., & Ho, K.K. (2023). How important is it to be beautiful? In Z. Sun (Ed.), *Handbook of Research on Driving Socioeconomic Development With Big Data*, pp. 320–340. IGI Global.

Litman, L., Robinson, J., Rosen, Z., Rosenzweig, C., Waxman, J., & Bates, L.M. (2020). The persistence of pay inequality: The gender pay gap in an anonymous online labor market. *PLOS ONE*, *15*(2), e0229383. <https://doi.org/10.1371/journal.pone.0229383>

Mathieu-Bolh, N. (2021). The elusive link between income and obesity. *Journal of Economic Surveys*, *36*(4), 935–968. <https://doi.org/10.1111/joes.12458>

Meara, K., Pastore, F., & Webster, A. (2019). The gender pay gap in the USA: A matching study. *Journal of Population Economics*, *33*(1), 271–305. <https://doi.org/10.1007/s00148-019-00743-8>

Mobley, L.R., Root, E.D., Finkelstein, E.A., Khavjou, O., Farris, R.P., & Will, J.C. (2006). Environment, obesity, and cardiovascular disease risk in low-income women. *American Journal of Preventive Medicine*, *30*(4), 327–332.e1. <https://doi.org/10.1016/j.amepre.2005.12.001>

Rothman, K.J. (2008). BMI-related errors in the measurement of obesity. *International Journal of Obesity*, *32*(S3), S56–S59. <https://doi.org/10.1038/ijo.2008.87>

Sarlio-Lähteenkorva, S., Silventoinen, K., & Lahelma, E. (2004). Relative weight and income at different levels of socioeconomic status. *American Journal of Public Health*, *94*(3), 468–472. <https://doi.org/10.2105/ajph.94.3.468>

Shinall, J.B. (2014). Occupational characteristics and the obesity wage penalty. *Vanderbilt Law and Economics Research Paper No. 16-12*, *Vanderbilt Public Law Research Paper No. 16-23*. <https://doi.org/10.2139/ssrn.2379575>

Sugiura, R., & Murata, M. (2011). Problems with body mass index as an index to evaluate physical status of children in puberty. *Pediatrics International*, 53(5), 634–642. <https://doi.org/10.1111/j.1442-200x.2010.03312.x>

Talumaa, B., Brown, A., Batterham, R.L., & Kalea, A.Z. (2022). Effective strategies in ending weight stigma in healthcare. *Obesity Reviews*, 23(10), e13494. <https://doi.org/10.1111/obr.13494>

Wang, Y., Beydoun, M.A., Min, J., Xue, H., Kaminsky, L.A., & Cheskin, L.J. (2020). Has the prevalence of overweight, obesity and central obesity levelled off in the United States? Trends, patterns, disparities, and future projections for the obesity epidemic. *International Journal of Epidemiology*, 49(3), 810–823. <https://doi.org/10.1093/ije/dyz273>

Abstracts

ARTS

Music Paintings and the Fashioning of an Early Modern Cardinal in Rome: The Case of Cardinal Francesco Maria del Monte

Charlotte Poulton

Utah Valley University

The display of paintings in seventeenth-century Roman palaces was integral to the social virtue of splendor intended to convey the owner's social, political, and, in the case of cardinals, ecclesiastical importance. Recent research has shed additional light on the careful consideration given to the particular rooms in which paintings were to be hung and viewed based on the rank and status of guests who were admitted into those spaces. In this case, we must reevaluate the presence of music paintings in the collections of Rome's intellectual and cultural elite. These paintings too often have been dismissed as a minor genre of merely descriptive representations of contemporary music practices. This paper investigates the social, cultural, and political implications of the display of music paintings by Caravaggio and Antiveduto Grammatica in the palace of Cardinal Francesco Maria del Monte. Parallel examinations of music paintings in the palaces of Marchese Vincenzo Giustiniani and cardinals Francesco and Antonio Barberini reveal similar patterns of display. These men were associates of Cardinal del Monte, and all were powerful patrons at the forefront of progressive developments in both painting and music in early seventeenth-century Rome. I demonstrate that while paintings of musical subjects are relatively few in number, surprisingly, they were hung in prominent locations in the private residences of Rome's most powerful and influential cardinals. The complexities of their subject matter and strategic display suggest that music paintings were instrumental in helping Cardinal del Monte achieve splendor and fashion himself as a leading arbiter of taste in both painting and music in Rome.

ARTS**Towards an Invention of Style: Encoding Aspects of the Twentieth-Century Post-Tonal Tradition for use in Contemporary Classical Solo Piano Improvisation****Evan B. Whitfield***Southern Utah University*

The innovations produced from the evolution in Western musical practice during the early twentieth century coincided with a decrease in the continuation of nineteenth-century classical improvisation traditions. This phenomenon coincidentally negated the legitimate development of twentieth-century classical piano improvisation. As the modern composer (e.g., Schoenberg, Stravinsky, Debussy) began profound explorations away from the late nineteenth-century Romantic tonal tradition, advancements in twentieth-century Western piano improvisation eventualized from the avant-garde movements in free-jazz and the works of serialist and indeterminate post-modern composers after 1945 (e.g., Cage, Stockhausen, Berio). The inevitable musicological question is: what would early twentieth-century classical piano improvisation have sounded like, if it had been allowed to flourish, adapting to a new environment of musical modernity from 1900 onwards? From my background as a contemporary improvising pianist, I proposed an experiment of purposeful programming, with the attempt to answer this fundamental, historical quandary. Akin to a computer software engineer, I began by encoding the most compatible musical techniques (those that elicited a high degree of probable synthesization for improvisational use) associated with the pioneering efforts of the post-tonal twentieth-century tradition, such as polymodality, octatonicism, pandiatonicism, polyrhythm, polytonality, and polymeter. These were then linked with a selection of established techniques of keyboard improvisation, such as parallelism (planing), contrapuntal invention (fugal and canonic), polyharmonic chordal arraying, and chromatic transpositional modulation. Once these mechanical processes were formatted, the next step involved constructing a new type of form and the use of graphic score realizations. The final step was the creation of thematic material from which an improvised development would transpire. A practice-as-research methodology was used to document the cumulative stages of programming. This paper will present a successful synthesization of early twentieth-century compositional techniques into an innovative codex for a new model of contemporary classical piano improvisation.

ARTS

Romantic Ballet and the Rejection of the Male Gaze

Roxanne Gray

University of Utah

Romantic Ballet is often defined by the ethereal female ballerina, on the tips of her toes, wrists soft and broken, head tilted coquettishly. The sylph is an icon, and she sets the stage for ballet as we know it. She bears the burden of feminist ridicule and is often blamed for the gender inequalities still steeped in contemporary ballet. Or rather, the male gaze by which she was formed is criticized. This article seeks to shift the perspective that women in the arts have spent centuries exclusively being manipulated and shaped by men. Flipping this narrative requires analyzing Marie Taglioni and Fanny Elssler's work and words in the context of existing French feminist theories, such as Saint-Simonianism. By viewing the female body as a site of resistance, we can assert a rejection of the male gaze in Romantic Ballet, seek to understand the historical context of the era accurately, and more fully analyze the contributions of women to early ballet as revolutionary beings.

ARTS

Sylphs Supporting Sylphs: Confronting Gender Binaries in the Classical Ballet Canon

Jamie A. Johnson and Christa St. John

Utah Valley University

Ballet has a long history of perpetuating gender binaries in pedagogy and performance. Twenty-first-century ballet, however, continues to evolve to include more expansive gender expressions and identities. Many works from the classical ballet canon emphasize heteronormative relationships and represent females as chaste, unobtainable, and otherworldly. To contribute our voices to the evolution of gender in ballet, we reimagined a historic piece for an ensemble of undergraduate college students and conducted an Institutional Review Board–approved study. In the case study, we explored how an all-female-identifying cast alters a work that seems to idealize cisgender relationships and a hypermasculine figure. We collected data generated by movement research, practitioner observations, and post-experience surveys. In the process, we confronted classic repertoire norms and historical gendering

practices. As Linda Caruso Haviland eloquently states, “There are no reconstructions of the past in the present that are ideology-free and all reconstructions construct a picture of the past that equally reflects what was and who we, as reconstructors and recontexters, are.” Reimagining canonical ballets provides an opportunity to present historic works while supporting a spectrum of gender identities and expressions.

ARTS

Visualities of Identity, Citizenship, and Place in Monument to the Rohwer Deceased

Jacob Jensen

University of Utah

The profoundly nuanced Monument to the Rohwer Deceased, 1944, has been subjected to repeated simplifications through documentary photography in archives, the addition of further monuments in Rohwer Memorial Cemetery, and comparison with other monuments nationwide. In contrast with more generalized memorials to the incarceration, the monument is a testament to the diversity and myriad experiences of Japanese Americans during World War II. Mixed visualities clue the viewer into the identities and struggles of the inmates of Rohwer Relocation Center, a wartime concentration camp (often referred to euphemistically as a relocation or internment camp) in Arkansas. Traditionally American features emphasize the desire of immigrants to gain or retain citizenship. Buddhist and Shinto iconographies defy the precedent of adopting Christianity as an integral part of assimilation. In this presentation, I discuss the monument through formal analysis, culturally specific visualities, and theories on localization to present a more rounded narrative of the incarceration and provide an interesting counterpart to contemporary art questions on the Japanese American displacement. Photography of the monument by different generations and ethnic groups plays an integral role in relocation memory work but advances a different understanding of the experience. My research attempts to distinguish national, personal, and other agendas of storytelling through consideration of current practices and methodologies of localization, memory work, and research on archives and monuments.

ARTS

Active Analysis and the Acting Classroom

Michael Shipley

Utah State University

Konstantin Stanislavski is considered to be the creator of modern acting technique, but his methodology changed radically over his career. Much of American actor training is based on Stanislavski's early work, characterized as "cognitive analysis" (or intellectual analysis). Late in his career, he began to work with an embodied method, which has become known as "active analysis" (in contrast to the previous cognitive analysis). Since it was most commonly used as a part of preparing a play for performance, active analysis is often referred to as a "rehearsal technique," yet how can we expect actors to engage with a rehearsal technique that may seem at odds with their previous training, likely based on some legacy of Stanislavsky's early work? Is it possible to introduce the concepts of active analysis into the acting classroom to better prepare actors for more in-depth and skillful use of the same concepts when rehearsing a play, providing an embodied approach to both training and rehearsing? This paper will describe a design for an embodied approach to an acting class based on the tenets of Active Analysis. This course, focusing on improvisation, events, and action, was created at Utah State University and will include feedback from students and observations from practicing teachers.

ARTS

Susan Chen and the Conditional Acceptance of Asian Americans

Natalie Bond

University of Utah

Recent events in the United States have drawn attention to challenges and complexities that exist for Asian American people surrounding identity and acceptance. Contemporary artist Susan Chen responds to the topic of Asian American lived experience through painted portraiture. This paper argues that through artwork created during the Covid-19 pandemic, Susan Chen addresses the conditional acceptance of Asian Americans in mainstream American culture. To support this argument, the paper first introduces the artist's identity and practice. It then

explores Chen's work on Asian American experience during the Covid-19 pandemic, focusing on how the artist addresses racialized blame. Finally, it addresses Asian American female representation and how acceptance of Asian American women is conditional upon balanced cultural beauty standards. The artist's motivation for creating pandemic art includes a desire for a broader representation of Asian Americans, awareness of Asian American issues, and social change. Susan Chen's work speaks to these issues in a contemporary context and with powerful visual storytelling. This project's findings include a close visual analysis of Susan Chen's works, which demonstrates her personal interest in Asian American issues. By depicting herself and others responding to racial prejudice and blame during the pandemic, Chen calls attention to the conditional nature of acceptance for Asian American people. Additionally, an analysis of her work through lenses of race and gender demonstrates how conditional acceptance is present at the intersection of Asian American and female identities due to beauty standards, especially those surrounding skin color, hair color, and dress.

ARTS

The Relationship Between Music Instruction and Academic Performance

Douglas Stump and Laura Peterson

Southern Utah University

The Covid-19 pandemic of 2020 is creating the need for many school districts to consider how to prioritize school budgets during a time of reduced funding. With school administrators placing greater emphasis on making data-driven decisions, it is critical to understand current research on music instruction and academic performance and how best to apply these studies in making policy and curriculum changes within our schools. The purpose of this paper is to advocate for music as core curriculum through a review of current studies that address the benefits of music instruction in the areas of overall academic performance and intelligence, mathematics, language learning, acquisition and reading, brain function and cognition, and student wellbeing. Music instruction provides clear academic and developmental benefits toward meeting state-mandated performance goals while providing equal access for students of low socio-economic and disadvantaged groups.

ARTS

Maya Deren's "Ritual in Transfigured Time": An Example of Avant-Garde Dance

Fiona Barnard

Southern Utah University

"Ritual in Transfigured Time" is a short dance film choreographed and directed by Maya Deren. The film was released in 1946 during the post-war era. Maya Deren utilized early modern avant-garde characteristics to create her work. Avant-garde works are created to derail art from a traditional position. Maya Deren, through modern dance and the avant-garde commonalities, produced a work that is a product of American post-war culture. Therefore, "Ritual in Transfigured Time" demonstrates the cultural affluence and individualities of the post-war era. Through the New Historicism perspective, I will analyze five avant-garde characteristics and how those characteristics are reflected in "Ritual in Transfigured Time." The five characteristics I will discuss are (1) exotic themes, (2) distortion of time and space, (3) spiritual transformation, (4) naturalism, and (5) addressing the social conflicts of the time. A review of written source material and a critical analysis of a YouTube video of "Ritual in Transfigured Time" will fully realize the purpose of this study and answer the following questions: (1) What is the New Historicism perspective and how does it inform a discussion of dance? (2) What are the characteristics and commonalities of modern avant-garde? and (3) Through a critical analysis of the movement, what characteristics and commonalities are seen in "Ritual in Transfigured Time"? These questions will provide the information needed to determine whether Maya Deren's work was informed by avant-garde principles. After researching, reviewing, and analyzing "Ritual in Transfigured Time" and written source materials, I conclude that dance is a product of a culture. Through the lens of New Historicism, Maya Deren's choreographic choices demonstrate all five avant-garde characteristics and commonalities to speak to the cultural climate of the post-war era.

BIOLOGICAL SCIENCES

Chimeric Autoantigen Receptor (CAAR) T cells as a Novel Immunotherapy for Autoreactive B Cells in Graves' Disease

Mackenzie Taylor Hansen, Abigail Johnson, Hunter Lindsay, Joshua Bennett, Kim L. O'Neill, and K. Scott Weber

Brigham Young University

Graves' disease is the fourth most common autoimmune disease in the U.S. The main cause of Graves' disease is the overstimulation of the thyroid gland by thyroid-stimulating hormone receptor (TSHR)-specific antibodies produced by autoreactive B cells. Current therapies for Graves' disease include antithyroid drugs, radioiodine therapy, and surgery, but these do not address the underlying mechanism of the autoimmune response. Our aim is to generate a targeted method to attack the disease using engineered chimeric autoantigen receptor (CAAR) T cells. Our CAAR T cells contain various epitopes of TSHR that autoreactive B cells will recognize, bind to, and activate. The activated CAAR T cell will then kill the autoreactive B cell. We will compare our candidate CAAR T cells to see which epitope expresses and binds most effectively. We will also perform cytotoxicity assays to measure the targeting and killing ability of our CAAR construct against B cells from Graves' disease patients. The use of CAAR T cells specifically targeting autoreactive B cells would open a new avenue of treatment for Graves' disease and potentially other autoimmune diseases.

BIOLOGICAL SCIENCES

Toxic Metal Sequestration Using Microfluidics

Jacob Kjeldahl Jensen and Christopher F. Monson

Southern Utah University

Toxic metals, including mercury, lead, and cadmium, are pollutants in many waters worldwide. Although many current strategies for heavy metal removal involve flocculation and precipitation, they also require holding ponds and significant amounts of time. Microfluidics offer the ability to remove metals specifically based on reduction potentials. Although microfluidics are inherently low capacity, they offer scalability and the opportunity to run with low power use. A microfluidic

device is being developed that should run on solar power, potentially offering the ability to remove metals in a quasi-equilibrium fashion.

BIOLOGICAL SCIENCES

A Genetic and Morphological Review of Southern Utah Bumblebees *Bombus morrisoni* and *Bombus nevadensis*

Isaac Sorensen, Jake Olvera, and Jackie Grant

Southern Utah University

Bumblebees serve an important role as pollinators, and many species are in decline. Effective conservation efforts rely on accurate species identifications that can be difficult. Southern Utah is home to many species, including *Bombus morrisoni* and *B. nevadensis*, which are challenging to differentiate despite being in different subgenera. The species' ranges overlap greatly and have characteristics that require time to understand and differentiate. We have observed that these species are inadequately represented in Southern Utah and other databases because of being misidentified. Digesting one species' cytochrome c oxidase subunit I sequence and running them through a gel has been used to differentiate the two.

BIOLOGICAL SCIENCES

An Examination of the Highly Variable P8 Region (trnL intron) in the Genus *Equisetum*

William Speer

Salt Lake Community College

Sequences covering the highly variable P8 region of the chloroplast trnL intron from 68 *Equisetum* specimens representing 17 species and 1 hybrid taxon were examined in this study. P8 sequence lengths ranged from 47 to 82 bp, with an average length of 71.2 bp. The length variation was mostly due to several mostly contiguous indels that were observed among the *Equisetum* species. These were mainly in a nucleotide region that was difficult to align between subgenera but not within subgenera. One indel reliably separated subg. *Equisetum* from subgenera *Paramochaete* and *Hippochaete*. Indel patterns were consistent among conspecific sequences except for *E. palustre*, *E. scirpoides*, *E.*

laevigatum, *E. myriochaetum*, *E. hyemale*/*E. praealtum*, and *E. ramosissimum*, which had identical indel patterns, as did *E. giganteum*/*E. xylochaetum* and *E. variegatum*. Sequences had a high average A-T content of 79.2%. Nucleotide positions more in the middle of the P8 appeared to exhibit higher variability and were more difficult to align, whereas positions closer to the 5' and 3' ends seemed to be more conservative and easier to align. The predicted secondary structures for the P8 region tended to be very variable between subgenera except for the monotypic subg. *Paramochaete*. Phylogenetic analysis of the P8 sequences used the maximum likelihood optimality criterion. Specimens representing subg. *Equisetum* were distinguished from subg. *Hippochaete* and the monotypic subg. *Paramochaete* (*E. bogotense*) with *E. bogotense* nesting in subg. *Hippochaete*. Conspecific specimens did group together in many cases; interspecific relationships within subgenera were generally not well resolved and often polytomous. However, P8 data did tend to reliably separate subgenera *Equisetum* and *Hippochaete*, although the position of subg. *Paramochaete* is somewhat questionable.

BIOLOGICAL SCIENCES

Effects of Tea Tree Essential Oil on *Escherichia coli* and *Staphylococcus aureus*

Robert T. Eakins, Jed Whetten, Taylor Roney, Quinn Legere, and Olga R. Kopp

Utah Valley University

Melaleuca alternifolia (tea tree) leaves have been used in many cultures around the world to help heal wounds and injuries because of their anti-inflammatory and anti-microbial properties. Some companies claim that tea tree essential oil contains purifying capabilities for air and contaminated surfaces. Essential oils are purified by many methods, the most popular being steam distillation. The essential oils, once purified, are sold to customers to use the oil to benefit from the plant's physiology and metabolic processes. We examined the antibacterial properties of the essential oil, we tested whether tea tree oil possesses the ability to fight common infections to any significant degree. We grew *Escherichia coli* and *Staphylococcus aureus* and measured the zones of inhibition in response to different concentrations and two different brands of tea tree oil, dōTERRA and Lagunamoon. We found that dōTERRA tea tree oil exhibited antibacterial properties whereas the Lagunamoon oil did not.

BUSINESS**Desired Leadership Traits in First Bosses: A Study of Extant Leadership Theories****James C. Brau¹ and Jameson L. Brau²***¹Brigham Young University, ²Gonzaga University*

In this paper, we document the extant theories of business leadership and partition them into main threads (e.g., great man theory, trait theory, contingency theory, etc.) Next, we examine the sociocognitive literature on Generation Z and formulate hypotheses of desired leadership traits in first bosses. We then conduct a comprehensive survey gathering data from 700+ undergraduate college students, asking them what preferred traits they would like to have in their first boss upon graduating from college. Empirical analyses are then conducted to test the various hypotheses pertaining to the extant leadership theoretical camps.

BUSINESS**An Empirical Examination of Inventory Turnover Along the Supply Chain****Joseph J. Henry,¹ Peter Christensen,² James C. Brau,² and Rebekah Inez Brau²***¹Rowan University, ²Brigham Young University*

Inventory turnover may directly or indirectly impact a firm's supply chain neighbors. If firms in the supply chain can collaborate, it is possible that neighboring firms' inventory systems both become more efficient. However, if a supplier must stock up on extra inventory to satisfy the downstream customer, the supplier's inventory system may become less efficient. We perform our analysis to determine whether there are positive or negative externalities associated with inventory turnover along the supply chain. We test two mutually exclusive hypotheses, the displacement hypothesis, specifically that suppliers and customers have negatively correlated inventory turnover ratios [$\rho(\text{ITC}, \text{ITS}) < 0$] and the integration hypothesis, that suppliers and customers have positively correlated inventory turnover ratios [$\rho(\text{ITC}, \text{ITS}) > 0$]. We perform econometric analyses to verify whether a firm's neighbors' inventory turnover is a statistically significant driver of the firm's inventory performance, and, if so, in what direction that relationship lies. Our

testing includes pairwise correlation analyses, as well as multivariate models at the firm-specific and industry levels. Our empirical evidence provides robust support for the integration hypothesis.

BUSINESS

An Econometric Analysis of Diversity: Perceptions of Emerging Adults towards Corporate Social Responsibility Metrics

James C. Brau,¹ Jameson L. Brau,² and Sabrina Volpone³

¹Brigham Young University, ²Gonzaga University, ³University of Colorado

The focus of this study is to examine emerging adult perceptions of diversity issues. We use a sample of 1,149 students and ask questions pertaining to how important diversity is in their ideal first job. The dependent variables are derived from a corporate social responsibility database and focus on diversity issues. We employ a set of econometric tests to find correlations between demographic independent variables and six dependent variables as well as an aggregate diversity index dependent variable. The tests show that gender and political affiliation are robustly correlated with the dependent variables.

BUSINESS

Can Environmental Messaging Reduce Product Returns?

Aaron Brough and Ryan Hamilton

¹Utah State University, ²Emory University

Many consumers have come to expect that the process of returning a product will be free and easy, and product returns are increasingly common. Last year, approximately one in six items purchased in the U.S. was ultimately returned. A high rate of product returns is problematic for two reasons. First, product returns harm the environment; they involve additional energy and resource consumption as returned products are repackaged and transported, and many returned products end up in a landfill. Second, returns place a heavy financial burden on retailers; paying for return shipping, inspection, restocking, reselling, and

reshipping quickly erodes profit margins and may even create a net loss, especially when a returned product cannot be resold. In this research, we propose eco-messaging (reminding consumers of the environmental impact of their decisions) as an inexpensive but effective method of reducing return rates. We provide evidence that eco-messaging creates anticipated guilt by making salient environmental costs that might otherwise be neglected. We further show that eco-messaging may be more effective among liberals than conservatives. These findings can help retailers improve profit margins and have important implications for fighting climate change.

BUSINESS

The Impact of ADHD and ASD on Learning in a Principles of Finance Class

James C. Brau

Brigham Young University

We analyze the impact attention-deficit/hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) on academic performance in an undergraduate introductory finance course. We implement univariate and multivariate econometric models on a sample of over 800 students from the Winter 2023 semester at a large, private university. Prior research by Brau et al. (*Business Education Innovation Journal* 2016;8(2):21-31 and *Journal of the Academy of Business Education* 2017;18:231-284) identifies factors that correlate with university student course grades. We employ the same research structure as these papers with the innovation of adding dozens of questions that deal with ADHD and ASD tendencies, as well as anxiety and depression characteristics.

BUSINESS

Unattended In-Home Delivery under Varying Scenarios of Technology-Enabled Anonymity

James C. Brau and Hugo A. DeCampos

¹Brigham Young University, ²University of Central Oklahoma

Whereas many companies have explored attended in-home delivery as one solution to challenges associated with last-mile delivery, few have

explored unattended in-home delivery. This paper examines consumer willingness to allow unattended in-home delivery under various scenarios of anonymity enabled by technology. Specifically, we study how blockchain-enabled anonymity of sellers, delivery companies, and consumers can influence consumer willingness to allow unattended in-home delivery of a nutritional product in this last-mile service triad. Hypotheses build on agency theory and the potential for information asymmetry and opportunism. The analyses are based on data from 784 responses to an online survey of end consumers who were randomly assigned to treatments in a scenario-based experiment. The results indicate that blockchain-enabled anonymity of the delivery company significantly decreases consumer willingness for unattended in-home delivery. These findings hold regardless of whether the consumer and seller are known or anonymous to one another. We also find that the joint anonymity of the seller and the consumer significantly decreases the likelihood of a customer allowing unattended in-home delivery.

BUSINESS

A Framework for the Integration of CFA and CFP Exam Preparation into an Undergraduate or MBA Course of Study

James C. Brau and Peter Christensen

Brigham Young University

In this paper, we first perform an exhaustive literature review of the extant peer-reviewed, academic research on the Chartered Financial Analyst (CFA) or Certified Financial Planner™ (CFP®) designations. This review motivates the potential benefits for students to work towards one or both of the designations. We then propose a framework and curriculum for integrating a CFA or CFP program into an undergraduate or MBA curriculum. We use as our case study a large, private university in the western United States. Using 13 years of data on CFA enrollment and passing rates, we find that the students who completed the proposed curriculum achieved an average 72% passing rate on the CFA Level I examination, compared with a national average over the same years of 39%, a statistically significant difference beyond the one percent level. We also present enrollment and depletion data for the CFP capstone class for its first four semesters.

BUSINESS**Blockchain in Supply Chain Management: A Feature-Function Framework for Future Research**

James C. Brau,¹ John Wallace Gardner,¹ Krista Marie Gardner,¹ and Hugo A. DeCampos²

¹Brigham Young University, ²University of Central Oklahoma

Blockchain technology offers numerous venues for supply chain applications and research; however, the connections between specific blockchain features and future applications have been unclear to date in its evolution. We advance the understanding of blockchain in supply chain management by providing a new research framework built on unique blockchain features as applied across core supply chain functions. Our framework is a 4×9 feature-function matrix that integrates four supply chain functions (i.e., logistics, purchasing and supply management, operations/quality, and customer relationship management) with nine blockchain features (i.e., traceability/provenance, accessibility, visibility, immutability, distributed/shared ledger, validity, peer-to-peer transacting, pseudonymity, and programmability). Our feature-function framework is supported by a structured systematic review of reviews using PRISMA methods. We use the framework to present a future blockchain research agenda in supply chain management.

BUSINESS**The Impact of Changing Disclosure Requirements, Competition, and Private Capital on Firm Exit Methods and Premiums**

James C. Brau,¹ Ninon Kohers Sutton,² and Qiancheng Zheng³

¹Brigham Young University, ²University of South Florida,

³University of Massachusetts Lowell

Changing disclosure requirements and the evolution of U.S. markets in the 21st century have created historic shifts in the exit strategies and payoffs for private firms. Prior literature demonstrates that firms choosing to exit by going public earn a greater premium than comparable firms that sell via mergers and acquisitions. We document that important changes in regulation, competition, and private financing in U.S. markets

are associated with a reversal in this pricing trend: firms that sell out earn higher risk-adjusted premiums than firms that conduct initial public offerings. Our findings are robust to regression discontinuity, propensity score, and Heckman methods, which all control for endogeneity concerns. We also document that several of the relevant explanatory factors in the prior literature have reversed their effects on both choice of exit and exit premium. We believe we are the first to document this reversal in the economics of the exit decision.

BUSINESS

Comparing Self Efficacy and Grades of Students in Progressive Accounting Course Levels

Jeff Davis

Weber State University

Self-efficacy has a long, rich research history and is defined as an individual's judgments of their own capabilities to perform an action. In other words, "How confident am I that I can do well on this test, in this sporting event, in this game, on this assignment, or in this course?" Confidence in one's abilities is an important aspect of success. Confidence usually increases as one increases their preparation, experience, and history of success. Confidence in an action usually has a positive relationship with how well a person enjoys doing the specific action. On the other hand, as an individual learns more and has more experience in a particular task, they also become more aware of the complexities, difficulties, and challenges of completing that task successfully. Thus, the more one knows, the more a person may realize how much more they need to learn, develop, and apply to continue to have success. For example, confidence in your abilities in a sport or musical talent will increase, but moving from high school level, to college level, to professional level, means competing against better competition in all aspects of the sport or musical performance. This study measures and compares self-reported answers to 10 self-efficacy questions for new, intermediate, and advance accounting students. The research reports self-efficacy differences in the course levels of the students. It also studies whether higher self-efficacy has a positive relationship with higher grades as reported by some prior research.

EDUCATION

Studying the Benefits of Peer Coaching during Student Teaching

Studying the Benefits of Peer Coaching during Student Teaching
Southern Utah University

In the fall of 2021, student teachers were placed in peer coaching groups. This decision was grounded in peer coaching research, which has shown a benefit to preservice teachers in a variety of ways. The intent was that these arrangements would provide support in a way that is typically missing during student teaching. Student teachers were asked to complete two different surveys following each peer coaching meeting. We sought to understand the impact and potential value of peer coaching. Although peer coaching was indeed found to be valuable by student teachers, what we did not expect was that the state-mandated performance assessment would negatively impact the student teaching experience. This study looks into that impact on student teachers and student teaching in general. We found that stress and overwhelm of the Performance Assessment for Teaching (PPAT) was prominent during the student experience and had a negative impact. This was seen in responses to prompts about their feelings, challenges, goals, and advice needed. As a result, in an attempt to mitigate this impact and relieve some of the stress on student teachers, in following semesters, they were permitted to take three work days off from student teaching to focus only on the completion of the various tasks of the PPAT. These findings imply that PPAT is adding undue stress and distracting student teachers from the important work and growth that is intended for student teaching.

EDUCATION

Sharing Experiences to Cultivate a More Open Mind about Teaching: A Co/Autoethnography of Pre-Collegiate Teaching Experiences

William J. Davis and Abigail Julian
Southern Utah University

Teacher learning is paradoxical: teacher preparation programs and courses seek to influence teacher learning at a given point in time, yet teacher learning is an ongoing experience influenced by past, ongoing,

and anticipated experiences. In response to research documenting the ways teachers' own experiences as K-12 or precollegiate students result in teachers teaching the way they were taught, teacher educators have conceptualized at least some of their research and teaching as an intervention against the detrimental impacts of K-12 school experiences. However, scholarship also has identified influences on teacher learning like parents, as well as teaching experiences students have in teaching internships, peer tutoring, and other precollegiate experiences. These additional influences, along with assertions in the literature that the expectations of the current era contribute to fundamentally different experiences with teachers and teaching in schools, suggest that teacher educators have much to learn about the ways in which the incoming education students' experiences shape their understandings of teaching. The purpose of this collaborative autoethnography between a teacher educator and an undergraduate student is to examine influential precollegiate experiences outside of K-12 schools, in particular experiences teaching in nonformal education (NFE) programs. We developed a series of five prompts that we responded to individually, meeting via Zoom to discuss our experiences and teacher learning. Our collaborative and iterative analysis revealed four categories related to our NFE teaching experiences: 1) how teacher learning was impacted by particular contexts in which it took place; 2) how our experiences revealed different and broader notions of teaching than we observed in our formal education experiences; 3) how certain contradictions shaped, and perhaps inhibited, our learning as teachers; and 4) what we learned from the teaching we did in NFE programs.

EDUCATION

Social Studies, Culture, and the Utah Dual Language Immersion Program: A Preliminary Didaktik Analysis

William J. Davis, Jiazhen Yan, Ruohan Gao, and Ziyao Zhou

Southern Utah University

Culture and language learning are inextricably linked, although the nature of their relationship is disputed. Descriptions of the relationship could be considered along a continuum, ranging from essentialist perspectives like E.D. Hirsch, Jr.'s cultural literacy to theories of bilingual learning and multicultural education. The relationship between culture and language learning has taken on increasing importance in Utah, where a state-sponsored dual language immersion (DLI) program

in multiple languages continues to grow. Utah's DLI program has been designed for native speakers of language to learn a target language, including Chinese, Russian, and Spanish, among others. Students participating in the program spend half of the day learning language and content in English, with the other half spent learning language and content in the target language. As a result of this split, the responsibility for teaching content areas like social studies, where standards can deal with different aspects of culture, may also be divided between teachers. These divisions raise questions about which cultures, and what aspects of culture, are being taught. The purpose of this study is to explore the formation of DLI students as language learners and the role culture may play in this formation. We conducted this examination by employing a Bildung-centered Didaktik analysis of the K-6 social studies standards and the online supports DLI teachers receive. Our goal has been to investigate how and why culture is taught within the program, rather than merely focus on what the explicit curriculum requires. In addition, we draw from interviews from a case study of teacher learning and professional development in a Chinese DLI program to contextualize our findings. Our preliminary analysis has revealed that the target language is typically used to teach about living in Utah, with the target culture rarely a topic of study despite the potential for cross-cultural comparison.

EDUCATION

Strengthening Teaching Self Efficacy of Adjunct Faculty Through Training and Community of Practice

Todd Wentz

Ensign College

For this study, several adjunct faculty members were invited to participate in a training protocol that included introduction of two constructivist teaching strategies and two community of practice meetings within the business faculty group. Instructors were evaluated on how their expression of teaching self-efficacy changed as measured with the Ohio State Teacher Efficacy Scale (12-item variant). Quantitative measures showed measurable gains in teaching self-efficacy among newer instructors. Qualitative measures suggested that all instructors became more comfortable discussing their self-efficacy, especially regarding using constructivist strategies after the protocol was implemented.

EDUCATION

Improving Teaching Self Efficacy Among New Adjunct Instructors through a Focused Innovation

Todd J. Wentz

Ensign College

New adjunct instructors often express feelings of being unprepared for the challenges of teaching in a collegiate environment, especially if they have not had the opportunity to go through a strong teaching skills program. Without such a program, they must do what they are familiar with from their own programs, which is often heavily lecture based and not taking advantage of the insights that come from an understanding of both constructivist strategies and andragogical principles. This study demonstrates that a focused unit of study can improve instructors' overall sense of teaching self-efficacy in a short period of time. Statistically significant evidence from qualitative analysis of pre and post surveys based on the Ohio Teaching Self Efficacy Scale is further supported by qualitative analysis from Community of Practice meetings that included both new and experienced instructors.

EDUCATION

“Mirrors, Windows, and Doors” Strategy: Equity-Centered Assignments in Teacher Education to Prepare Culturally Responsive Teachers

Andrea Garavito Martinez

Weber State University

In this presentation, I focus on how I use the equity-centered approach to facilitate assignments and activities that prompt teacher candidates to examine their assumptions of self and others. I refer to this strategy as “mirrors, windows, and doors.” Mirror activities are designed for individuals to look inward through self-reflection, Windows activities are for them to look outward using an equity- and asset-based lens, and then doors refers to the praxis of applying what they have learned through inward and outward reflection. This strategy for assignments and activities in teacher education prepares teacher candidates to work with culturally and linguistically diverse students. They learn to interrogate bias, use an asset-based view of students, and value the

experiences of students from marginalized groups. More importantly, they learn that through continuous learning and pushing themselves through reflection, they will become better and more effective teachers.

EDUCATION

Math Pals: Connecting Discourse and Feedback

Megan Kimberling and Nicole Gearing

Utah Valley University

Throughout the past year, the authors have been working to create a program called Math Pals. Math Pals uses a program called Explain Everything to digitally connect an elementary student to a college student. Through this program, we use a virtual whiteboard and a voice recording feature to communicate with our math pal. The elementary students are given a math task and try to solve it. They are able to record themselves writing and talking while working out the problem. Then their digital whiteboard is shared with their college student math pal. The college student watches their recording and sees how their math pal did with the math task. They can then record feedback, extra instruction, or extra help to their elementary student. This has been an amazing program that gets young students excited for learning math and college students more hands-on experience teaching and guiding a student to success.

ENGINEERING

Effective Thermal Conductivity of Porous Copper Foam Saturated with Eicosane Phase Change Material

MaryJo Taylor and Ali S. Siahpush

Southern Utah University

A detailed experimental study has been performed to evaluate the effective thermal conductivity of a solid/liquid phase-change thermal energy storage system that includes porous copper foam. The phase-change material (PCM) and metal foam were contained in a vertically oriented test cylinder that is cooled at its outside boundary, resulting in radially inward freezing. As the PCM freezes, the solid/liquid interface moves inward from the surface of the test cylinder, and a thermal resistance layer is built up, resulting in a reduced heat transfer rate

between the system to be cooled and the PCM. The porous copper reduced the insulating effect of this thermal resistance layer. In the freezing case study, a one-dimensional mathematical model was developed, which considered heat conduction as the only mode of heat transfer. Experimental results were used in the heat conduction and heat balance integral methods to evaluate the effective thermal conductivity. Also, six analytical models were used to predict the effective thermal conductivity. The results of this study are discussed in terms of the effectiveness of the metal foam as a heat transfer enhancement device.

ENGINEERING

Studying Natural Convection through Melting a Slab of Ice

Manuel Gaspar, Toby McMurray, Matthew Bayreder, Slater Emery, and Ali Siahpush

Southern Utah University

Natural convection, though very complex, is an important concept in heat transfer, because it helps explain many of the earth's natural systems. The purpose of this experiment was to study natural convection by melting a slab of ice and comparing the result with an analytical solution. Specifically, the mass flow rate of the melting ice was measured and predicted. The average measured mass flow rate was 280.79 g/hr while the predicted was 172.56 g/hr. These values exhibited a 62.72% error. This large percent error could be attributed to a multitude of factors including improper enclosure conditions around the ice slab and assumptions associated with the analytical approach.

ENGINEERING

Boiling and Cavitation Experiment for Engineering Undergraduate Labs

Savanah Higley and Ali S. Siahpush

Southern Utah University

The phase-change process is an important concept to understand in fluid mechanics and thermodynamics as a mechanical engineering undergraduate. To better understand this process, experimental

demonstrations are needed, but the required equipment is often too expensive to implement in an undergraduate lab. In this experiment, an inexpensive and practical apparatus was used to measure the lower-than-atmosphere pressure at which water begins to boil at various temperatures. The experimental data were then compared with published values and theoretical values calculated by using the Clausius-Clapeyron and Magnus equations to show the success of the experiment. This experiment proved to be an accurate way to predict the pressure at which water begins to boil, because the experimental values were very close to the published and theoretical values. Further uses of this experiment include a fluid mechanics lab on cavitation or a thermodynamics lab on saturation pressure.

ENGINEERING

Plane Wall Radiation Shielding

MaryJo Taylor, Michael Forbes, Tori Thomas, and Ali Siahpush

Southern Utah University

This experiment modeled radiation shielding by using an aluminum plate as a radiation shield. The shield is placed between two parallel thin sheets of aluminum. One aluminum sheet is uniformly heated and the other one is not heated. The temperatures of each metal sheet are recorded after the heat source turns on until the system reaches steady state (3-6 hours). The experiment was repeated after placing a thin sheet of aluminum between the original aluminum sheets as a radiation shield to reduce the thermal radiation heat transfer. The experiment was repeated four times for varying distances between the aluminum sheets. Using the rate of heat transfer coming from the heating source, the temperature of the back plate is calculated and is used to determine the theoretical temperatures. These theoretical temperatures are then compared with the experimental temperatures. When spacing was smaller, theoretical calculations yielded imaginary numbers. It was found that the expected heat transfer rate coming from the heating source was expected to be 24 W, but using experimental values the actual heat transfer rate was only 2 W. This was because of heat loss through convection. Even with this loss, the aluminum plate still shielded the radiation heat transfer, and with larger spacing the shielding was more effective.

ENGINEERING

Lumped Method Transient Conduction Heat Transfer

**Sergio Reyescordova, Ethan Arnold, Kaden Allred, William Miller,
and Ali Siahpush**

Southern Utah University

In this experiment, we tested multiple configurations of aluminum and examined their validity as a lumped system. For a material to meet the requirements of the lumped system, it must have a uniform temperature throughout. To test this validity, each configuration was submerged in hot water then immediately cooled in ice water. The experimental changes in temperature of the configurations were recorded and used with the log-incomplete response of the temperature change to find the time constant. The time constant was used with the lumped system analysis heat transfer equations to evaluate the heat transfer coefficient of the fluid. This was then used to evaluate a Biot number, which must be less than or equal to 0.1 for the lumped system analysis to be valid. The Biot numbers of each trial were found to be less than 0.1, verifying that all the configurations can be considered lumped systems.

ENGINEERING

Heat Transfer of a Fluid and a Water Reservoir Using a Constant Temperature

**Sota Nakahama, Adam Smith, Aaron Chancellor, Ammon Heaton,
and Ali Siahpush**

Southern Utah University

The development of thermal science technologies throughout time has been greatly aided by advancements in heat transfer analysis. Therefore, efficient heat transmission is critical to the continued advancement of technology. In such a broad field as heat transfer analysis, there are many exciting opportunities for undergraduate research. The objective of this project was to set up and test a preliminary design for a heat exchanger to be used for undergraduate engineering research. In a heat exchanger, a working fluid heats or cools another fluid without any mixing occurring between the two fluids. To replicate this concept, the system consisted of a constant temperature bath connected to a water reservoir. The working fluid was delivered in a counterflow configuration from the constant temperature bath fluid reservoir to heat or cool the water in the

container (cooler). Temperatures were recorded with thermocouples at specific locations within the system and water bath and compared with the ambient temperature. Tests were performed for heating and cooling to better understand the efficacy of the design. The heat loss in the system to the surroundings was significant and proved to be the single largest inhibitor of accurate results. A future study using this preliminary design must be focused on limiting this loss of energy.

ENGINEERING

Natural Convection Over a Heated Vertical Plate

**Jordan Peterson, Drew Hatch, Braeden Brown, Jordan Katnik,
and Ali S. Siahpush**

Southern Utah University

In natural convection, the temperature difference between a fluid and a hot surface causes a change in fluid density. In the case of a heated vertical plate suspended in air, this density change causes buoyancy forces to push the air up. The upward movement of air causes an airstream that allows natural convection to occur. The thermal boundary layer thickness is the perpendicular distance away from the surface where ambient air is unaffected by convection. The goal of this project is to investigate the natural convection boundary layer thickness over a vertical plate using imaging techniques, theoretical analysis, and experimental measurements. In this experiment, an aluminum sheet (8×8-in) receives constant uniform heat flux from a heating source and heats to approximately 75°C. Schlieren imaging is used to visualize the thermal boundary layer of the heated vertical plate. Preliminary thermocouple experimentation showed the maximum thermal boundary layer thickness is approximately 1 in with a heat supply of 30 W. This testing assists in determining the thermocouple spacing for the final experiment. Thermocouples will be attached to a rod at regular 1/8-in intervals. The temperatures measured by the thermocouples will determine the boundary layer thickness by determining how far away from the plate the measured temperature is the same as ambient air temperature. This project is a work in progress, and further calculations will determine a theoretical boundary layer thickness of the plate. The result will be compared with the boundary layer thickness measured in the experiment. The experimental heat transfer coefficient will also be compared with theoretical values.

ENGINEERING

Infinite Length Fin Heat Transfer Analysis of Aluminum Rod in Unforced Air

Lee Bistline, Jameson Griffiths, Tommaso Manghera, Rebecca Moses, Kadyn Tucker, and Ali Siahpush

Southern Utah University

This paper describes an analysis that was performed on a cylindrical fin exposed to unforced air to better understand the coefficient of convective heat transfer. It was designed to compare the analytical solution of heat transfer through a fin to experimental fin results. The experiment was set up by making a fin from a 0.5-inch aluminum rod. The fin was exposed to the air and heated at the base by a heating pad. The heated plate was insulated to prevent heat loss to the environment. Thermocouples attached at specified distances from the heat source measured the temperature throughout the rod. To analyze the heat transfer through the rod, steady-state and transient conditions were modeled using MATLAB to predict the transient heat transfer. When comparing the finite difference numerical model against the data collected during the experiment, the results strongly supported the accuracy of using such an analysis to predict fin behavior.

ENGINEERING

Comparative Analysis of Urban Railway Construction: High-Speed Train from Salt Lake City, UT, to Las Vegas, NV

Mohamed Askar, Jared Baker, Reagan Robins, Jake Richins, Jet Richins, and Kordell Baker

Southern Utah University

Constructing a high-speed transit train from Northern Utah to Las Vegas will significantly reduce the amount of traffic on Interstate 15. By putting a high-speed train route, other means of cargo routes will be developed to be able to speed up the transit of goods from one state to the other. The model discusses three alternative railway routes to select which of the three alternate designs is ideal for construction. This will be determined by analyzing several criteria of selection, including construction time, life cycle costing, risk, speed of the train, revenue,

environmental impact, and land acquisition. Each of these criteria will be given a relative weight according to its effects on the constructability. After analyzing each route and giving weighted averages to each of the factors, an overall score can be given to the route alternative that would reflect the constructability of the route. This study is a substantial help to the design-build project because it is invaluable information to the owner that summarizes which route is most effective overall. The research's primary goal is to find the best routes through the rough terrain between Cedar City, Utah, and Mesquite, Nevada. With there being lots of elevation changes, the research is investigating the most feasible route that will accommodate the most people but not compromise the whole purpose of putting a high-speed train in for quick transport through the state of Utah.

ENGINEERING

Quality Control System for Heavy Civil Construction Projects: Cedar City Water Tank Case Study

Mohamed Askar, Jared Baker, Tanner Woodruff, Porter Weston, and Tanner Wright

Southern Utah University

Tracking and carefully observing an array of quality control factors help a construction company ensure the quality of projects while also meeting time and budget constraints. Based on the tracking of quality control, many companies are impacted in a positive way when quality control is met. Construction quality control is a system of management that ensures that deliverables meet the standards and guidelines set by the client at the beginning of the construction process. This can include a number of criteria, such as completing the project within the scope of work. In the end, quality is decided by the client, regulatory bodies, and U.S. Environmental Protection Agency guidelines. Quality control and quality assurance are two equally important arms of construction quality. Whereas assurance refers to setting quality management expectations, quality control refers to the plans and procedures that achieve high-quality outcomes. Quality control in construction seeks to solve problems, provide high-quality results, and prevent issues from coming up again in the future. A quality control model will be developed, and the defined steps will be followed in sequence. The previous water tank had settled, and a better quality system could protect it from settling again.

ENGINEERING

Constructability Assessment Model for Heavy Construction Projects: Garnet Interchange, Clark County, NV, Case Study

Mohamed Askar, Jared Baker, Maxwell Mansfield, and Eddy Ngoie

Southern Utah University

Reconstruction of ramps and other required improvements decrease congestion, generate healthy travel settings along the vital corridor, and develop strength and economic opportunities throughout the community. The research develops a model to discuss the constructability assessment of the reconstruction of the on- and off-ramps to provide adequate acceleration, replacement of the existing I-15 bridges, modification to the US 93/SR 604 intersection, and intersection improvements at US 93/Apex Great Basin Way, including coordination of design efforts with the City of North Las Vegas on the future relocation of SR 604. These improvements will enhance the storage length for turning traffic; accommodate crossing roadways, vertical clearance, and adequate width for future widening of I-15 to three lanes in each direction; and provide access and satisfactory traffic operation in conjunction with the adjacent I-15/US 93 interchange. The model examines which of the three alternate designs given is ideal for construction. This will be determined by analyzing several criteria of selection, including time, cost, risk, safety, and environmental impact. Each of these criteria will be given a relative weight according to their effects on the constructability. After analyzing each design and after giving weighted averages to each of the factors, an overall score can be given to the design alternative that would reflect the constructability of the design. This study is a substantial help to the design-build project because it is invaluable information to the project owner by summarizing which design is most effective overall.

HUMANITIES, PHILOSOPHY, FOREIGN LANGUAGE

Dissolving The Twin World Problem

Jordan Robert

Brigham Young University

The twin world thought experiment has, it seems, stripped away Gottlob Frege's conception of sense and reference as argued by philosophers like Burge, Kripke, Putnam, and Donallin. This, however, I suggest can be resolved by appealing to Wittgenstein's distinction between a sign and symbol in his philosophy of logic. Once we understand what it is that picks out an object in logical space, we can, therefore, see how philosophers can ensnare themselves in the so-called "meaning" and "referent" nexus that plagues so much of epistemology and philosophy of mind. I suggest that we revisit Wittgenstein to clarify the meaning of this distinction showing via Wittgenstein's picture theory of meaning that the sense in which our signs, e.g., "aluminum," change from world 1 to world 2 lies not in the object (reference) or in the meaning (use), but the possibility of the sign in reference (symbolizing). This is the result of a misunderstanding of logical space and significant use. Once we bring into view what makes symbolizing possible via our signs (an ideograph or that temporal object perceivable to the senses), we can free ourselves of being puzzled by such thought experiments and dissolve the problem "like a lump of sugar in water" (Wittgenstein, *Philosophy*).

HUMANITIES, PHILOSOPHY, FOREIGN LANGUAGE

Make Haste Deliberately: The Historical American Aversion to Inoculations and its Ramifications

Thomas C. Terry

Utah State University

Joel Valdez languished 11 days in a Houston hospital, waiting for surgery after being shot six times during a robbery. Ray DeMonia of Cullman, Alabama, reportedly contacted 43 hospitals in three states searching for an open cardiac intensive care unit bed for him and eventually died. Three hospital groups in Salt Lake City, swamped with Covid-19, postponed 'not immediately life-threatening surgeries' causing William, 11, born with multiple heart defects, to have two surgeries canceled in early November 2021. All fell victim to what U.S. Centers for Disease Control and Prevention director Rochelle Walensky

called an ‘epidemic of the unvaccinated.’ This is nothing new. In 1721, Rev. Cotton Mather, of Salem Witch Trials notoriety, supported the then-experimental inoculation procedure of variolation to combat a smallpox outbreak brought in Boston. A bomb was hurled through the window of his home at 3 a.m., failing to detonate. Attached was a note: ‘Cotton Mather... I’ll inoculate you with this...’ In 1776, Congress forbade physicians from inoculating soldiers for smallpox. George Washington defied them, believing the Continental Army had more to dread “from [the disease] than from the Sword of the Enemy,” completing the successful and mandatory mass inoculation of his army in January 1777. In late 2020, government officials postponed vaccine Emergency Use Authorization decisions for the Thanksgiving holidays, ignoring the example of a Thanksgiving Day 76 years earlier when U.S. and allied soldiers liberated the Natzweiler-Struthof Nazi concentration camp near Strasbourg, Germany, rather than pausing for a turkey feast. This article looks at vaccine hesitancy in American history, aided and abetted by politicians and confusing, contradictory, and sometimes deadly public health behavior by the CDC and U.S. Food and Drug Administration, including repeated reauthorization of the infamous Tuskegee Study of Untreated Syphilis of 400 poor Black men in Alabama from 1932 until 1969 and the denial that AIDs could be transmitted through transfusions.

HUMANITIES, PHILOSOPHY, FOREIGN LANGUAGE

Hegel’s Relation to Metaphysics

Alexander James

Utah Valley University

The sense we have of the subject matter of metaphysics, inherited from both antiquity and the modern period, is of a subject that deals either with the transcendent first-cause—and if not with one that is transcendent, then one that is only immanent—or, on the other hand, if not addressing the topic of the first-cause, as a subject constituted by its occupation merely with ontology, the theory of categories, or transcendental philosophy. I call this the ‘standard frame of reference’ for getting the subject matter of metaphysics into view. I suggest this either—or has influenced the way we think about the possibilities for interpreting Hegel’s own relation to metaphysics, in the sense that this either—or has provided a template through which commentators have explored Hegel’s own relation to metaphysics. Indeed, the standard space of options for thinking about Hegel and metaphysics tends to map on to the possibilities

outlined by just this either–or. Yet, I want to suggest that Hegel’s philosophy is in no small part the effort to overcome just this sense of the possibilities for thinking about the subject matter of metaphysics. That is, his philosophy is committed to overcoming what I am calling the ‘standard frame of reference’ for thinking about the subject-matter of metaphysics. For Hegel, it is neither the case that metaphysics is a subject matter dealing either with a metaphysical first-cause that is either transcendent or immanent, or, on the other hand, merely with a general ontology or with a theory of categories or with a transcendental philosophy (i.e., a theory of the mind’s immanently necessary categories).

HUMANITIES, PHILOSOPHY, FOREIGN LANGUAGE

Ethnographic Study of Mormon Faith Difference

Kim Abunuwara

Utah Valley University

This project researches the effect of religious difference on Mormon parent–child relationships. Jana Riess’s Next Mormons Survey (*The Next Mormons: How Millennials are Changing the LDS Church*, 2019, New York: Oxford University Press) details these differences. Although many millennial Mormons are believers like their elders, their belief is softer on traditional Christian teachings like ‘Jesus was literally resurrected and rose from the dead’ or ‘There is life after death.’ Riess writes, “the percentage who aren’t sure that God exists has doubled from the oldest generation to the youngest” (16). Jeffrey Nielsen’s editorial “LDS Church Losing Youth to its Moral Conscience: Why the LDS Church Should Be More Accepting of LGBTQ and Transgender People” (*Salt Lake Tribune*, April 17, 2022) recounts how frequently his students speak to him about feeling alienated from their Mormon parents. This study involved surveys with local volunteers asking Mormon parents and children about their habits when talking about religion. Interviewees were informed that their words would be recorded and used in subsequent performances. Researchers curated the interviews and then were video-taped reading select passages. Researchers were also video-taped reflecting on their experience with the project. These performances will furnish an interfaith website—a safe place where visitors can explore and reflect on differing views without the complex emotions that accompany a relational encounter. The goal of ethnographic performance is not illusionism but to activate audience contemplation.

For example, the performer's physical type often does not match that of the person interviewed; the words may indicate a middle-aged man, but the performer/researcher is a young woman. This incongruity causes the audience to consider the whole exchange as well as the individual viewpoints. Jill Dolan writes, "The opposite of parody or satire which are mean and mocking, the monologue performance invites understanding of otherness. Leads to a more generous compassionate attitude toward difference."

KINESIOLOGY AND HEALTH SCIENCES

Developing Nursing Student Clinical Judgment Skills Through Active Learning Simulation Experiences

Carolyn Lewis

Utah Tech University

Nursing students who attend Utah Tech University participate in four semesters of active learning through simulation. The simulation experiences provide hands-on experience with low- and high-fidelity mannequins to help the students develop and solidify important clinical judgement skills that are tested on the National Counsel Licensing Examination for Registered Nurses (NCLEX-RN) and that are also essential to the nurse's success in the clinical practice setting. This presentation will describe the six facets of clinical judgement and will discuss the specific hands-on simulation activities that are used to target development in each of the six areas of clinical judgement. Nursing clinical judgment skills are categorized into six main areas: 1) recognize cues; 2) analyze cues; 3) prioritize hypotheses; 4) generate solutions; 5) take action; and 6) evaluate outcomes. During each semester of the nursing program, students take care of simulated patients' clinical problems. The faculty control the patient simulators out of sight behind a two-way mirror. The high-fidelity mannequins can speak and manifest real signs of distress including adventitious breath sounds, irregular heart rhythms, thready pulses, pupillary changes, etc. During simulation, students are required to assess the patient, recognize problems, take actions to address the problems, call the physician for medical orders, gather supplies, manage their patient's care, and document their interventions in a time-pressured environment that simulates a real patient care setting. After the simulation experiences, students have a chance to debrief and complete self-reflection and goal setting.

KINESIOLOGY AND HEALTH SCIENCES

Using Substance Abuse Counselor Interview as An Engaged Learning Component of An Online Health Promotion Course

Linnette Wong

Weber State University

Substance Abuse Prevention is a senior level online course for students seeking a Bachelor's degree in Health Promotion. Historically, this course had the learning objective of helping students study legal and illegal drugs from a pharmacological, historical, psychosocial, and behavioral perspective with an emphasis on primary prevention concepts and responsible consumerism. In recent years, the addition of a substance abuse counselor interview as a key component of the course has established a link between engaged learning and substance abuse issues. This component is a good start for students to get involved in the profession and to learn more about substance abuse issues.

KINESIOLOGY AND HEALTH SCIENCES

The Effects of Probiotics of Group B *Streptococcus* Rates in Pregnant Women

Jake Reed, Hailey Tennessee Schellenberg, Robert Taylor Eakins, and Michaela Gazdik Stofer

Utah Valley University

Group B *Streptococcus* (GBS) is a bacterial species commonly found in the vaginal tract of ~40% of pregnant women. GBS-positive women are not sick but can pass the bacteria to the infant during birth, leading to possible complications for the child. GBS infection in the infant can lead to an increased risk of the infant developing sepsis, pneumonia, meningitis, and in some cases death. Pregnant women are tested for GBS using a vaginal swab when they are 36 weeks pregnant. According to U.S. Centers for Disease Control and Prevention guidelines, patients who are GBS positive will be administered antibiotics 4 hours prior to delivery. Pre- and intrapartum antibiotics can adversely affect the development of the infant's immune system, resulting in an increased risk for allergies, asthma, obesity, and eczema. A hypothesized solution to combat GBS colonization in pregnant women is the taking of

probiotics prophylactically to prevent GBS from colonizing, and/or eliminating GBS after it has infected the vaginal tract. There have been few clinical trials done on the effects of probiotics on GBS, with only two taking place in the United States. We hypothesize that if pregnant women take a probiotic every day beginning at week 28, they will have a decreased likelihood of contracting GBS. We have currently enrolled 9 pregnant women to participate in our study and are actively collecting data to address our hypothesis. Participants take a vaginal swab at week 28 to test for the presence of GBS. At that point, probiotics are given to participants, and one capsule will be taken daily until the end of their pregnancy. At 36/37 weeks of pregnancy, the patient's provider will perform another vaginal swab to test for GBS.

LANGUAGE AND LITERATURE

Exodus to Eden: Biblical Journey Narratives in *My Ántonia*

Emma Fox

Brigham Young University

Willa Cather's novels are known for their lyrical language, midwestern imagery, gripping immigrant characters, and diverse portrayals of the immigrant experience. While all of Cather's novels have helped establish our sense of distinctively American spaces and narrative types, *My Ántonia* creates an especially poignant version of the American frontier myth focused on the hardy but often maligned Eastern European settlers of the northcentral plains. As Cather ennobles the immigrant status of these pioneers by imagining them as biblical figures on a kind of biblical journey, she positions them as venerable models positioned to lead established Americans into a new age. My presentation connects the immigrant experience in *My Ántonia* to distinct narratives in the books of Genesis and Exodus. Initially, the Shimerdas imagine themselves as Old World exiles who, following a long exodus, establish themselves in the "promised land" of the American Midwest. But as they learn that the new land is no Eden, that it is instead harsh and unforgiving, they struggle for physical and emotional survival. Ántonia eventually seeks Edenic promise in the town several miles from the family homestead. But in an inversion of the Eve narrative, Ántonia "falls" and is exiled from the town as well as from idyllic memories of her past. Ultimately, however, she initiates a personal exodus, reclaiming a corner of the countryside as her own and establishing a new and enduring Eden within

it. Cather's final imagery in *My Ántonia* creates the text not only as a model immigrant journey but as a beacon to all Americans, a bright reminder that the raw integrity and determination of the immigrant American is and always will be the heart of the American future.

LANGUAGE AND LITERATURE

Margaret Hale's Strike Against Immoderate Male Feelings: Emotional Responsibility in Elizabeth Gaskell's *North and South*

Madison Maloney

Brigham Young University

In Elizabeth Gaskell's *North and South*, men exhibit immoderate emotion, and their excessive cowardice, sorrow, and impulsiveness leads to dark consequences. Because the men deny responsibility for their own feelings, they shrug off the attendant consequences as well, and Margaret Hale, the novel's protagonist, must manage the emotional burdens of the men around her. Predictably, as Margaret represses her own feelings so she can be more emotionally available for others, she is threatened with burnout or collapse. *North and South* uses an overlaying story about workers' strikes to develop crucial undergirding themes of the masculine parading of emotion in tension with the female suppression of feeling. In the end, the novel argues that men and women should live in emotional equilibrium by assuming equal levels of emotional responsibility. Although Margaret's familial and romantic relationships are important themes in the novel, emotional imbalances inhibit these connections. Emotional responsibility becomes a necessary remedy to create healthy, fulfilling relationships.

PHYSICAL SCIENCES

Quantitative Analysis of Mitragynine in Commercial Kratom

Products

Naomi Elmer, Amanda Meyers, and Edward Walker

Weber State University

Mitragyna speciosa, also known as kratom, is an indigenous tree in Thailand, Myanmar, and Malaysia with a rich folklore describing various biological activities including analgesic effects. Clinical studies suggest that Kratom tea has the potential to be an effective alternative to opioids for pain relief. The active ingredients are believed to be a variety of alkaloids, with the most important ones being mitragynine (MIT) and 7-hydroxymitragynine (7OH-MIT). However, Kratom products are sold under a variety of trade names with no data regarding the chemical composition of plant material being consumed. We utilized high-pressure liquid chromatography to measure MIT and 7OH-MIT in a number of commercially available products. Our test results show significant differences between the MIT concentration label claims and the actual MIT contents in some of these products.

PHYSICAL SCIENCES

Manganese Desert Rose Nanoparticle Synthesis

Taytum Stratton, Simon Langlois, Nakelle Goldie, Christopher Monson, and Elizabeth Pierce

Southern Utah University

Nanoparticles are of significance because of their small size and unique characteristics. Few studies have been conducted on the synthesis of manganese nanoparticles. This project was among the first to synthesize manganese nanoparticles, and this was done using a microfluidic device with manganese acetate as an ion source and sodium dithionite as a source of oxide. Various capping ligands were used, including FusionRed, oleic acid, green fluorescent protein (GFP), bovine serum albumin (BSA), casein, and fluorescent dyes. The FusionRed protein was expressed and purified in *Escherichia coli*. As different capping ligands were used for the manganese nanoparticles, different shapes and sizes of particles formed. Fluorescence spectroscopy and scanning electron microscopy were used to confirm that the particles synthesized were in the nanoscale size range. When FusionRed was used as a capping ligand, desert rose nanoparticles formed. In our investigations, it was noted that when water sources used for solutions were changed, the desert rose nanoparticles stopped forming. This implies that the desert rose nanoparticle fabrication process is highly sensitive to one or more trace contaminants in the water (all water sources were deionized). We are currently investigating this.

PHYSICAL SCIENCES

Holey Frit: Patterned PDMS for Protein Filtration

Kylee M. Stoddard, Fielding Hokanson, Hunter Cook, and Christopher F. Monson

Southern Utah University

Frits are filters that can remove micrometer-sized particulates from solution and are typically fabricated from glass beads. We have developed a method to make frits by mixing magnesium particles and PDMS, a silicone elastomer, followed by magnesium dissolution. Our frits exhibit surprising abilities to remove large molecules from solution, at times showing the ability to exclude 66-kDa proteins and possibly smaller molecules. They are also more heat stable than traditional dialysis membranes and so might offer significant advantages. Additional applications of the PDMS frits are being explored, including superhydrophobicity.

PHYSICAL SCIENCES

Collisional Losses and Reduction of Thrust in the Nozzle of a VASIMR

Benjamin Miera and Phil Matheson

Utah Valley University

A Variable Specific Impulse Magnetoplasma Rocket (VASIMR) is a potential means of powering future deep space missions. The engine uses radio waves to heat the plasma through ion cyclotron heating, which then creates thrust in a magnetic nozzle. Our previous studies have modeled the increased specific impulse and thrust generated in a collisionless plasma. This work includes ion-neutral collisions in the simulation, which reduce the number of ions in the plasma stream and thus reduce thrust. This study analyzes the loss of thruster efficiency caused by such collisions in the nozzle region of the VASIMR. The simulation follows argon ions passing through the engine and uses Monte-Carlo methods to evaluate collisions and ion losses along the ion trajectories. The collision rates are based on a background neutral density calculated from mass flow rates and ion temperatures obtained by averaging over the ion energies determined from our collisionless model. The neutral density is assumed to fall off exponentially after exiting the engine in the exhaust plume. The efficiency of the engine varies widely with initial mass flow

rates and the subsequent neutral backgrounds these produce, but in a nominal run of this model, using a mass flow rate of 120 mg/second and an initial ionization fraction of 95%, we find that the engine experiences a minimal loss of thrust.

PHYSICAL SCIENCES

Experimental and Theoretical Analysis of Resonance Energy Transfer Among Methylene Blue and Rhodamine 6G in Aqueous Solution

Hamza Samha and Jacob Dean

Southern Utah University

Methylene blue has the ability to sensitize oxygen in living tissue after being exposed to light at an efficiency of 50%. As a result of this characteristic, methylene blue is widely used as a phototherapy agent in the fight against cancer. To increase the efficiency of methylene blue to greater than 50% or expand the range in which methylene blue absorbs light, it can be combined with other light-absorbing molecules (dyes), such as rhodamine 6G. Initially, spectroscopy methods such as UV-vis and fluorescence spectroscopy were used to determine improvements in the potential sensitizing behavior. With this information, these dyes were then combined and fluorescence spectra were recorded to determine whether energy transfer via resonance energy transfer has occurred. However, several attempts proved futile, indicating that the concentration of the dye solution was not enough to form the necessary dimer needed for resonance energy transfer to occur. This prompted a computational analysis to investigate at what concentration will the dimers form for resonance energy transfer to occur and what conformer(s) will exist thermodynamically at the lowest possible energy state to yield the most stable dimer? Theoretically, the dimer at the lower energy state will be a viable candidate for the successful transfer of energy to in turn either increase the efficiency of the sensitization of oxygen or allow for spectra greater variety of wavelengths to excite methylene blue. In addition to a thermodynamic investigation, an analysis of ideal equilibrium conditions for monomers and dimers in aqueous conditions was considered. Furthermore, this will allow for a fitting of the data to maximize the concentration of methylene blue and rhodamine R6G in aqueous solution. This will allow for a range of concentrations that will be ideal for further future experimental investigation.

PHYSICAL SCIENCES

Electrophoretic Stripping

Logan Larsen and Christopher Monson

Southern Utah University

Cell membranes are essential parts of living cells, separating the inside of a cell from the external environment and supporting protein complexes that perform essential functions. Membrane proteins are proteins bound within the cell membrane that play a fundamental role in the upkeep of the cell but are difficult to analyze because of their need for a membrane. To mimic cell membranes, supported lipid bilayers have been developed, which are lipid bilayers held a few nanometers above a flat support, often glass. Previous research has shown that a supported lipid bilayer can be stripped off of glass using fast fluid flow; the lipid bilayer will peel off of a surface and form a vesicle containing whatever fluid was used. Research has also shown that proteins within the cell membrane can be separated by charge, lining up each unique protein by running it through high voltage. We are developing a device that will combine electrophoresis and stripping by running high voltage over a supported lipid bilayer and then running fluid over the membrane to form vesicles of purified proteins. This should facilitate the separation and thus characterization of membrane proteins in the cell, allowing us to gain a better understanding of the workings of the proteins within the cell membrane. Several previous devices have failed due to water leakages and air bubbles, both of which prevent the utilization of the device. We have solved the water leakage issue and are now working on removing the bubbles from the glass slide before we can do further testing.

PHYSICAL SCIENCES

On the Schrödinger Equations of Atoms in Lower Dimensions

Chin-yah Yeh

Salt Lake Community College

The Schrödinger equation of hydrogen-like atoms started the quantum era. There are only a few exactly solvable Schrödinger equations. Here we shall consider qualitative descriptions of two Schrödinger equations that are the analogs of hydrogen-like atoms in lower dimensions.

In 1-D, the equation is $-\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} + k\sqrt{x^2} \psi = i\hbar \frac{\partial \psi}{\partial t}$ and, in 2-D, $-\frac{\hbar^2}{2m} \left(\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} \right) + k(\ln r) \psi = i\hbar \frac{\partial \psi}{\partial t}$. Characterizing these equations may shed light on the study of 1-D and 2-D crystals. Things we see in 2-D but not 1-D include rotation and that a closed curve can separate a space into two regions. Things we see in 3-D but not 2-D include 3-D chirality and the fact that a closed curve cannot separate a space into two regions. In describing the two equations qualitatively, we shall focus on the distribution of energy levels and the behavior of degeneracies.

PHYSICAL SCIENCES

Cooling a Monolignol of Lignin to Near Absolute Zero as a Novel Alternative Method for Refining Organic Fragments

Seth Weston, Hannah Chappell, and Jacob Dean

Southern Utah University

Lignin is the second most abundant material in biomass. Breakdown of lignin while refining the organic fragments has potential for various applications. Lignin is composed of three monolignols each bearing methoxyphenol chromophores, which absorb ultraviolet light. Characterization of the fragmentation patterns of the monolignols is essential to designing more efficient tools for the breakdown of lignified biomass and has commonly been analyzed via enzymatic reactions. The purpose of this study is to explore a novel and controllable method that involves mass spectrometry coupled with laser spectroscopy to characterize fragmentation pathways of methoxyphenol compounds. This is accomplished through supersonic expansion, time-of-flight mass spectrometry coupled to a high-powered laser, which reveals photochemical fragmentation pathways in a mass- and energy-resolved fashion of a compound at 2 Kelvin. Advantages of this method include a more accurate analysis of intermolecular forces, molecular/electronic structure, and a number of other physical characteristics at molecular resolution. Prior to loading the sample, characteristics such as the melting point, UV-vis, molecular weight, and time-of-flight of guaiacol (2-methoxyphenol) were determined. Results show that under these conditions, fragments appear at lower energy levels compared with normal fragmentation patterns.

POSTER: BIOLOGICAL SCIENCES**Brain-eating Amoeba Rescue-of-infection Model using Drug Combinations****Isaac Roy, Karissa Bauer, Antonio Fazio, Kennedy Lewis, Kemri Stilson, and Daniel N. Clark***Weber State University*

Naegleria fowleri, a free-living amoeba capable of causing fatal human infections of the central nervous system, is commonly known as the “brain-eating amoeba.” The organism is the causative agent of primary amoebic meningoencephalitis (PAM), an extremely rare and typically fatal infection. The danger of this organism is largely due to the rapid deterioration of brain tissue that occurs upon infection, and diagnosis of infection largely occurs postmortem. Of 154 documented cases in the United States, only 4 people have survived *N. fowleri* infection. Typical PAM treatment requires an empirical approach, by testing drugs with unknown efficacy. We are testing five drugs that the U.S. Centers for Disease Control and Prevention mentions as potentially useful: amphotericin B, azithromycin, fluconazole, miltefosine, and rifampin. To evaluate which single-drug and combination-drug treatments will be most effective in clinical settings, we are using a rescue-of-infection model where cultured human HeLa cells are infected over several days until ~50% cytotoxicity is observed. Rescue tests were performed by adding drugs and observing the cell viability of the infected human cells (apoptosis levels). Combinations of drugs were able to kill *Naegleria* and protect HeLa cells from cell death. These results provide a greater understanding of the pathogenesis and treatment of this devastating infection.

POSTER: BIOLOGICAL SCIENCES**CRISPR Deletion of Viral Receptors****Dylan Salas, Rylan Schmanski, Branden Brooks, Bryson Taylor, Mason Masters, and Daniel N. Clark***Weber State University*

Enterovirus 71 (EV71) and herpes simplex 1 (HSV-1) are viruses that cause skin lesions in humans. EV71 is a virus that causes hand foot and mouth disease (HFMD) and primarily affects young children, sometimes fatally. HSV-1 is a lifelong infection, causing genital herpes and cold

sores, which affects 50 to 80% of US adults. In this experiment, we use CRISPR to edit the human genome in cultured cells (HEK293 and HeLa) to decrease the infectivity of these two viruses by deleting their receptors. To delete these receptor genes (*ANXA2*, *SCARB2*, and *SELPLG* for EV71 and *NECTIN1* and *HVEM* for HSV-1), a guide RNA (gRNA) was designed for each receptor. Plasmids that express each gRNA and the CRISPR cutting enzyme, Cas9, were transfected into human cells using the base plasmid All_in_one_CRISPR. This plasmid contains an mCherry fluorescent protein and a hygromycin selectable marker for the selection of edited cells. To confirm knockout, DNA was extracted and sequenced and compared with the wild-type genome. Several patterns of knockout were observed, including off-target edits. Infection assays compare infectivity in parent cells versus receptor-deleted cells via microscopy and gene expression levels by RT-PCR. Because viruses use combinations of receptors, the end goal is to determine which receptors are most critical for attachment and entry into cells to target those receptors for virus inhibition.

POSTER: BIOLOGICAL SCIENCES

Ditch the Stress: How Mindfulness Activities Affected Perceived Stress and Mood in University Students During the COVID-19 Pandemic

Jayden Peacock, Korina Ziegler, Colton Davis, and Dylan Gardner
Southern Utah University

Mental illnesses are a large concern in educational campuses, especially since the outbreak of COVID-19 and the impact it had on student lives, both social and mental. Our purpose was to determine the effectiveness of mindfulness activities on decreasing stress levels post-activity (PA) and one week (W) after. Students participated in an event where they took a self-reported intake (IN) survey measuring their current stress levels. Then, they were allowed to participate in four different activities of their choosing (paying someone a compliment, reflecting on good things that happened to them during the week, coloring pages, and being led in a muscle relaxation routine). After they had completed the activities, a self-reported PA survey was given to measure their change in stress levels. Each person was sent another self-reported survey in one week to measure which activity, when practiced for that week, had the greatest effect in lowering their stress levels. There were two activities with significant decreases in stress between the IN, PA, and W surveys:

coloring pages (IN vs. PA: $p=0.021$; IN vs. W: $p<0.001$) and progressive muscle relaxation (IN vs. PA: $p<0.01$; IN vs. W: $p=0.002$). The other two were not found to have significant decreases between the three surveys: paying a compliment was found to have a significant decrease in IN vs. PA ($p=0.024$), but it did not show the same trend in the IN vs. W ($p=0.164$). Positive weekly reflection did not have any significant decreases (IN vs. PA: $p=0.70$; IN v. W: $p=0.129$). Because there were activities that were more effective in decreasing perceived stress levels, they should be employed in educational campuses over long periods of time.

POSTER: BIOLOGICAL SCIENCES

Ability of Phage Penetration in *Staphylococcus aureus* Biofilms and Potentially Act Synergistically with Antibiotics

Alexis Koplín, Rainey Hughes, Yeshaswini Dudde, and Daniel N. Clark

Weber State University

Antibiotic resistance is a problem of great concern in the medical community, with bacterial resistance to antibiotics increasing proportional to their use; antibiotic use has never been higher. *Staphylococcus aureus* bacteria such as methicillin-resistant *S. aureus* (MRSA) can cause fatal infections and are known for antibiotic resistance. The problems associated with this resistance are compounded when the infecting bacteria form a biofilm. Biofilms are thick, sticky layers of bacteria and their secretions, and they are difficult for antibiotics to penetrate. Biofilm formation is common in hospital settings, such as on stents, catheters, and IV lines. Biofilms also make antibiotic treatment risky because of incomplete killing—the most resistant bacteria survive exposure. Interestingly, there is some evidence that bacteriophage (the viruses that infect bacteria) can break up biofilms, which may make them more susceptible to antibiotics. We induced a biofilm formation using a bioreactor, TSB broth, and the *Rosenbach* MRSA strain. Once the biofilm formed, we tested concentrations of antibiotic (oxacillin and vancomycin) with a phage (phage K) to determine MRSA killing. A Tecan plate reader was used to evaluate bacterial growth via absorbance measurements at 595 nm as well as visual cloudiness. We found that combinations of antibiotic and phage increased MRSA killing compared with phage or antibiotic alone.

This research is designed to find more efficient ways to treat MRSA. Bacteriophage used in combination with antibiotics may be able to better clear a biofilm infection compared with antibiotics alone while reducing the risk of antibiotic resistance.

POSTER: BIOLOGICAL SCIENCES

Generation and Characterization of Zebrafish Model to Examine the Pathophysiological Mechanisms and Treatment of Wolfram Syndrome 2

Rosemary Mwithiga, Youssef Harraq, Reign Krieger, and Hung Yu Shih

Utah Tech University

Wolfram syndrome 2 (WFS2) is a rare disease in which patients show premature aging with degeneration in multiple tissues. Mutations in the *cisd2* gene have been identified to cause WFS2; however, it is still far from clear how *cisd2* dysfunction causes WFS2. This research project aims to establish a zebrafish model of WFS2 to understand the pathophysiological mechanism and screen potential compounds for treatment. The CRISPR/Cas9 technique was used to knock out the *cisd2* gene of zebrafish. We further confirmed the *cisd2* knockout by high-resolution melting analysis. We are currently validating this knocked out model by examining the cell senescence markers analyzed in the mouse model. We will analyze the gene expression of cell cycle regulators such like *tp53*, *cdkn1ca*, *cdkn2a/b*, *ccne1* and *ccng1* by RT-qPCR as well as the cell cycle markers *pcna* and *ki67*. The aging cells usually accompany with cell apoptosis; we will further examine apoptosis by TUNEL assay. After validation, this model will be used to study the pathophysiological mechanisms of WFS2 as well as screening for therapeutic compounds for WFS2.

POSTER: EDUCATION**Looking for What Educators Need to Meet the Needs of English Language Learners****David R. Byrd, Shernavaz Vakil, Melina Alexander, and Denise Wright***Weber State University*

English language learners (ELLs) are one of the fastest growing populations in schools. These students require special attention in schools and classrooms to ensure success both academically and socially. Unfortunately, too few educators feel prepared to teach ELLs effectively. Often schools and districts try professional development (PD) to prepare educator to more effectively deliver quality instruction to their students, including ELLs. PD is often heralded as one of the most effective ways to enhance teacher practice by enhancing the professional knowledge, skills, and attitudes of educators. One type of PD, known as the Learner Centered Professional Development (LCPD) model, is a three-phase model that links research and knowledge-based strategies with school engagement, using collaborative teams (teachers, administrators, and caregivers) to actively construct knowledge as they work together. Our study looks at the first step of implementing LCPD for ELLs in one district in northern Utah. Using grounded theory, we analyzed data sources that described collaborative team members' ideas and needs for them to work together to improve equity and access to learning for ELLs. Our findings indicate that the team members needed to work through some significantly convergent and divergent thoughts on the hierarchy of problems and strategies to co-construct a plan to move forward to the second phase of the LCPD model. Our findings have implication for both pre- and in-service teaching situations.

POSTER: EDUCATION**How and What Principals Need to Know to Support Special Education Teachers****Mallory Poole***University of Utah*

The key factors in creating an environment for equitable student outcomes for students receiving special education services are prepared

and experienced teachers who are supported by administration leadership. When these factors are in place, the important factor, the retention of teachers in special education, becomes almost automatic. Students with academic deficits and behavioral disabilities struggle to achieve academic progress and stay at grade level. Studies in recent decades have clarified the linkage between special education teacher retention and local administrators. The finding that students with disabilities continue to struggle with poor outcomes, combined with the knowledge of the positive impact of teacher retention, suggests that effective and knowledgeable administrators are essential. DeMatthews et al. (2020, *Journal of Research on Leadership Education*) explained that a significant body of research describes how most principals are not prepared to lead diverse teacher and student populations. This research includes leading individuals with disabilities. They argue that without the proper training and in-depth study of the history of education discrimination, few principals are prepared to implement the policies necessary to promote inclusion effectively. This knowledge can help Local Educational Agency principals develop appropriate (e.g., legal, practice) educational decisions to support educators and promote equitable outcomes for students. If creating equity for all is the purpose and function of education today, then some well-identified deficiencies must be corrected. Educational leaders at the Local Educational Agency level, specifically the school principals, need more training and field experience supporting teachers of special education and working with individuals in special education. This study explores how leaders who are recognized for their support of teachers of special education are influenced by their training and preparation and how their experiences shape their leadership practices.

POSTER: ENGINEERING

The Arduino Platform as a Cost-Effective Field Data Collection Tool

Jake Olvera

Southern Utah University

As conservation efforts are ramping up, the need for accurate biological field measurements becomes apparent. These measurements are usually collected using multiple specialized, expensive devices. For example, soil characteristics (temperature, humidity, and salinity) can be measured using the Aquaterr EC-350 at a price point of \$1350. Similarly, the

Kestrel 3500 Weather Meter measures humidity, pressure, temperature, wind speed, and wind direction for the price of \$200. We used readily available sensors that communicate via I2C controlled by an Arduino Uno Rev3 development board to create a single, compact device. This device can measure pressure, altitude, temperature, humidity, soil temperature, and soil humidity for under \$100. A similar approach can be taken for other projects to create custom equipment that is accurate, cost-effective, and modular.

POSTER: PHYSICAL SCIENCES

Natural Language Processing with Quantum Computers

Thomas Draper

Brigham Young University

The first real natural language processing algorithm to be run on a quantum computer was released in 2020, sparking great research interest. English sentences can be parsed according to grammatical rules. The meaning of a sentence is a function of its words' meanings and their grammatical relations. We compute this meaning using quantum circuits with two main parts: representing word meanings and applying grammatical relations. After optimizing circuit gate parameters with a machine learning method, the circuit predicts a truth value for the sentence. We give an example of this process, walking through the quantum circuit corresponding to the sentence "Romeo who loves Juliet dies."

POSTER: PHYSICAL SCIENCES

Oxidation of Indoline with Ruthenium(III) Chloride

Matthew Prater and Wyatt Evans

Southern Utah University

Indole is a biologically relevant compound used to form the amino acid tryptophan and indole alkaloids. Traditionally, indole is prepared via the Fischer indole synthesis. Indoline, the dihydrogenated derivative of indole, is often made through a variety of methods, including transition metal catalysis, organocatalysis, and radical cyclization. We

hypothesized that Ru(III) could oxidize indoline to indole and be reduced in the process. Our earliest reactions had a lustrous metal precipitate, indicating reduction had taken place. Indole was then isolated to confirm its production. Current work is focused on developing a catalytic cycle by using a secondary oxidant.

POSTER: PHYSICAL SCIENCES

Conservation of the Endemic Coral Pink Sand Dunes Tiger Beetle, *Cicindela albissima*

Kate A. Ehlert, Dylan T. Gardner, Kayla C. Walker, Fredric R. Govedich, Bonnie A. Bain, Samuel A. Wells, and Rachel T. Bolus
Southern Utah University

Coral Pink Sand Dunes, located in southwestern Utah, is a unique desert dune system that has a number of endemic species including the Coral Pink Sand Dunes tiger beetle, *Cicindela albissima*. This species of tiger beetle has adapted to the unique conditions found in this dune environment. Geographical separation between this system and other similar systems has resulted in the speciation of this tiger beetle, but it has also meant that this species is potentially sensitive to any changes in its environment. Anthropogenic impacts such as recreation and climate change have resulted in fluctuations in the number of individuals of *C. albissima*. This study has focused on monitoring the population of adults and larvae of this sensitive species to ensure its continued survival. This project is supported by the U.S. Bureau of Land Management, Utah Department of Natural Resources, U.S. Fish and Wildlife Service, University of Utah, and Southern Utah University.

POSTER: PHYSICAL SCIENCES

Superhydrophobicity of Micro-patterned PDMS

J. Fielding Hokanson, Russell M. Bodily, and Christopher F. Monson
Southern Utah University

Superhydrophobic surfaces can prevent fogging in laboratory goggles, eyeglasses, and mirrors, improving optical clarity in humid conditions. These surfaces also prevent icing on airplane wings, reducing damages

and crashes. Superhydrophobic surfaces are surfaces on which water has a contact angle greater than 90 degrees. Such surfaces are commonly created using micropillar patterning; spaces between these pillars create a superhydrophobic effect as air repels water. Whereas some have used carbon nanotubes coated with zinc oxide, we have patterned polydimethylsiloxane (PDMS) to make superhydrophobic layers. Unpatterned PDMS is somewhat hydrophilic, exhibiting a contact angle of ~60 degrees. We have developed a method to create a superhydrophobic layer of PDMS by combining PDMS, magnesium, and hexane into a slurry and spinning it onto a glass slide. Once spun, slides are baked to evaporate hexane and polymerize PDMS, and a reaction with HCl removes magnesium. Data are quantified via contact angle (using a goniometer) and light scattering (using a homemade light scattering instrument). The micropatterns created by the magnesium allow for contact angles ranging from 80 to 120 degrees.

POSTER: PHYSICAL SCIENCES

Study of the Photophysical Properties of N,N'-bis(salicylidene)-1,2-ethylenediimine in Polar Solvents

Jackson Reese and Hussein Samha

Southern Utah University

The effects of water, methanol and ethanol as solvents on the spectroscopic properties of N,N'-bis(salicylidene)-1,2-ethylenediimine (Salen) Schiff base were studied. The absorption and emission of Salen were recorded in solution mixtures of water-acetonitrile, methanol-acetonitrile, and ethanol-acetonitrile. The position and intensities of the absorption bands are sensitive to the solvent ability of hydrogen bonding. The use of water-acetonitrile solvent mixture significantly enhances the intensity of the absorbance band of Salen centered at 404 nm. The enhancement occurs at the expense of the absorbance band around 317 nm as indicated by an appearance of one isosbestic point at 336 nm. This $\pi \rightarrow \pi^*$ electron transition produces a strong emission at 505 nm that was not observed in pure acetonitrile solution. Methanol and ethanol show the same effect.

POSTER: PHYSICAL SCIENCES

Direct One-pot Grignard Formation and Addition to Imine Electrophiles

Kaden Jensen, Austin Flynn, and Matthew B. Prater

Southern Utah University

Grignard reagents are commonly used in organic synthesis. The magnesium causes the carbon to be nucleophilic. It has been shown that an organohalide, in the presence of magnesium, will form a Grignard reagent. Traditionally, addition of a Grignard to an electrophile occurs via a two-step process: preparing the Grignard reagent and adding it to the electrophile. We propose to form the organomagnesium nucleophile in the presence of the imine electrophile, allowing it to directly add and form an alkyl amine. Preliminary results have been promising.

POSTER: PHYSICAL SCIENCES

Changes in Intrinsic Tryptophan/Tyrosine Fluorescence (ITF) as a Method to Study Conformational Changes in Oxidized Proteins

Steven Rimmasch and Tracy Covey

Weber State University

Determining protein structure is of extreme importance because it pertains to drug development, discovery of protein function, and identifying disease states in cells. Similarly, identifying different conformational changes proteins experience plays a role in all the previously mentioned disciplines as well as how the cell recognizes and reacts to these altered proteins. Protein structure and subsequent conformational changes can be determined with a high degree of accuracy through methods such as X-ray crystallography, Cryo-EM, and nuclear magnetic resonance. However, these methods are time consuming and difficult and require expensive equipment. Here, we aim to develop a lower resolution intrinsic tryptophan/tyrosine fluorescence (ITF)-based method to determine changes in protein structure due to oxidation and relate this to how proteins are selectively digested. Bovine serum albumin (BSA) has been used as our model protein to determine changes in protein structure. Our results show that hydrogen peroxide-treated BSA has a concentration-dependent change in ITF compared

with non-treated BSA. This suggests that oxidized BSA undergoes a conformational change that alters the exposure of its tryptophan and tyrosine residues to the solvent. I will discuss my work using ITF as a fast, easy, low-resolution method to probe structural changes in BSA and other proteins exposed to various conditions.

POSTER: PHYSICAL SCIENCES

Nucleophilic Aromatic Substitution of Nitrophenyl Sulfonates with Grignard Reagents

Ashley C. Hartwig and Nathan S. Werner

Southern Utah University

The hypothetical nucleophilic aromatic substitution reactions of Grignard reagents with 2-nitrophenyl tosylate, 4-nitrophenyl tosylate, 2,4-dinitrophenyl tosylate, 2-nitrophenyl mesylate, 4-nitrophenyl mesylate, and 2,4-dinitrophenyl mesylate were studied. The Grignard reagents evaluated were methylmagnesium chloride, ethylmagnesium chloride, iso-propylmagnesium chloride, tert-butylmagnesium chloride, n-pentylmagnesium chloride, cyclopentylmagnesium chloride, cyclohexylmagnesium chloride, and benzylmagnesium chloride. The Grignard reagent was introduced to a solution of the sulfonate under an atmosphere of argon gas. Different reaction solvents and temperatures were explored. Ultimately, the desired product of nucleophilic aromatic substitution was not observed in any of the experiments conducted. All reactions completely consumed the sulfonate starting material. Some reactions yielded a complex mixture of products, while others yielded the homocoupling product of the Grignard reagent. Further investigations would focus on the isolation and identification of the minor reaction products of the complex mixture.

POSTER: SOCIAL SCIENCES

Law and Order Effect and Implications

Ayden Bash, Kalynn Livingston, and Danielle Noorda

Snow College

Within the courtroom, biases and presumptions of innocence and guilt have been a major concern for those in the fields of criminology and

psychology, particularly the effect media has on presumptions and juror decision-making. Some research suggests that exposure to “CSI” and other related media has no direct effect on juror decision-making and in contrast, whereas other research suggests that exposure to pretrial publicity does affect juror decision-making. With the synthesis of this, we hypothesize that there is a possible presence of a pro-prosecution bias when exposed to dramatized criminal programs and pretrial publicity, which we call “The Law and Order Effect.” To test this, we will survey Snow College students to ascertain whether they watch dramatized crime programs and an estimation of how much time they spend watching the related media. We will have three groups, two of which will be exposed to shows and dramatized legal proceedings that influence biases (one where the defendant is innocent and other where the defendant is guilty). The control group will consist of people who will be exposed to a neutral program. After they watch the corresponding media, they will be given a mock court proceeding of which they will judge whether the defendant is guilty or innocent and judge accordingly on a scale of how much they believe the defendant is guilty or innocent.

POSTER: SOCIAL SCIENCES

Commonalities among Women’s Birth Stories: What Makes Experiences Similar or Different between Women?

Tricia Thalman, Morgan Smith, Kylie Bloomquist, and Kade Simmons

Snow College

There are a lot of unknowns and fears for both men and women surrounding pregnancy and the birthing experience. Because of the variety in experiences of women’s birthing stories, learning more about birth through parenting books can help ease some of these fears. Where parenting books fall short is sharing real-world experiences from a wide variety of mothers in different situations. Age, religion, medicine, and other factors all play a role in pregnancy and delivery. These factors may not be accounted for in other research. Some topics that are commonly researched include labor and delivery process, treatment in hospital, and differences among races. Another widely explored variable is trauma associated with pregnancy and birth. We are looking at factors that have not been thoroughly researched, such as religious affiliation, coping strategies of mothers during childbirth, relationship status, support from

family, and how these factors tie into topics that have been previously studied. After collecting and evaluating these data from a variety of mothers, we will create a database as a resource for future parents to utilize as they prepare for this new stage in their lives. The database will be easily accessible and will include personalized birthing stories for future parents to gain knowledge from. With this research we hope to improve the birthing experience.

POSTER: SOCIAL SCIENCES

Utah's Conspiracy Theory Beliefs

**Trevin Nielsen, McKenna Benson, Jose Patino, Braden Johnson,
and Emma Wallace**

Snow College

Our group's research efforts are centered around finding the traits that could lead to a belief in conspiracy theories among Utah residents. We are interested to see whether residents in Utah are more likely to have a strong belief in conspiracy theories compared with those of other states. We want to see whether the results correlate directly with the religious culture attached to the region, as well as examining correlation with other physical, ideological, and personality traits such as race, sexual orientation, political ideology, social media usage, etc. The method we will use to acquire this information is a survey distributed to Utah locals in the Ephraim area that will give us a general understanding of these locals' backgrounds. These subjects will fill out these previously mentioned background questions and give answers on a scale based on how strongly they feel about specific topics. We will ask participants about different conspiracy theories and their willingness to believe in them. We will then ask for the subjects' thoughts on some of the most well-known and controversial conspiracy theories and will even place a couple counterfeit theories to see if people are willing to believe in these as well. We will then compare the results of Utah residents with the results of studies done on the general American population to see whether there are any notable differences in Utah residents. We suspect that Utah residents, compared with people from other states, will be more inclined to have stronger beliefs in support of conspiracy theories because of the doubt in authority outside of the ideological beliefs they support. Our hope is that during this process we can find logical reasons to help explain why people believe in the things they do and gain a better understanding of this underdeveloped research topic.

POSTER: SOCIAL SCIENCES

Recognizing Sexual Assault

**Whitney Nielson, Eliana Hadley, Nettie Graham, Kelsie Tippetts,
and Sydney Morrill**

Snow College

The definition of sexual assault has been changed and distorted throughout time. With this widespread modification, we wanted to define the generational and gender differences among definitions. Previous research has been done within workplaces and school locations, while focusing on feelings of safety and resolutions of sexual assault. This research is valued and respected, but there is a lack of unification in the varying definitions. We will gather information through a survey given to people aged 18 years and older and of all genders and races available to us. We hypothesize that there will be differences between generations and genders and what they believe constitutes as sexual harassment. Those in older generations will probably view fewer actions and behaviors as sexual harassment. Another section of research we hope to contribute to is the fear of actions perceived. We recognize that our research is limited to the population of Utah, and a sample that is predominantly white and middle class. There is also the possibility that those we survey may not be transparent in their answers. However, this research is still important because sexual harassment is becoming more of a problem in everyday life. Conducting this survey and the resulting study will be an important step towards more insight into how differing opinions towards sexual harassment shape our society.

POSTER: SOCIAL SCIENCES

Establishing and Clarifying a Modern Definition of Cyberstalking as well as Analyzing the Different Applications between Men and Women

Jessie Romo, Azlyn Ristine, Landen Nielsen, and Alaric Martinez

Snow College

The purpose of our research is to redefine and modernize the term “cyberstalking” and to take into consideration modern social media and technological advancements. We believe our research is necessary because the current definitions are misused and specific for certain social

media platforms, for example; “insta-stalking, Facebook stalking, social media stalking, and cyberbullying.” Our research is necessary to better educate anyone using the internet and will benefit future generations. We will also note the different uses and applications of cyberstalking between men and women. Current definitions of cyberstalking tend to focus on electronic communication and harassment or physical harm, but as a part of our research, we are going to imply that cyberstalking does not have to include harassment or contact with the victim. In addition to benefiting future generations, our research could be helpful for legal cases of cyberstalking. We plan to distribute surveys to college students in Utah as our methodology to collect data and social definitions of cyberstalking. We also plan to get information from the subjects that include their age, gender, race, and other defining characteristics and behaviors that could be relevant to our study. In one of the surveys, we will ask respondents what they think the definition of cyberstalking is, what they believe cyberstalking to be, what social media platforms they use, and how often they check social media. With the second survey we distribute, we will have students examine scenarios to determine whether they consider the actions to be cyberstalking based on their own opinion. While our research progresses we hope to gain insight from professional sources and institutions to accomplish our objectives further.

POSTER: SOCIAL SCIENCES

Let’s Jam: Can Music Alter the Response to a Stressor?

**Ryan Coburn, Vitaliy Walker, Tatiana Leroy, Austin Booth,
Bethany Blair, Brittney Stockholm, Crystal Tejada, Hannah
Momoh, Lorely Olguin, and Manuel Quijas Ornelas**

Utah Valley University

In a stressful situation, the human nervous system reacts with the fight-or-flight response. Physiological indicators of the fight-or-flight response include an increase in body temperature, heart rate, and sweating. Recent research has found a correlation between chronic exposure to stress and the development of mental illnesses such as anxiety and depression. Furthermore, chronic stress has the potential to change the anatomy of the brain along the hypothalamic pituitary adrenal axis, an important part of the neuroendocrine system that plays a role in the release of stress hormones and helps regulate moods, emotions, and sexual behaviorisms. Because college can be quite stressful, developing healthy coping mechanisms might positively influence the students’

academic performance and improve and maintain their psychological and physiological well-being. Music can effectively relieve nervousness, promote mental health, and positively affect students' psychological state. Current research on stress-related outcomes shows that music intervention can result in stress reduction. The present study focuses on measuring physiological responses (including heart rate, heart rate variability, electrodermal skin response, and body temperature) to stressful situations (a mathematical calculation task) while being exposed to two music genres. We hypothesize that relaxing music will reduce the stress response, while fast, upbeat music will increase the stress response in response to the mathematical calculation task. The study employs a within-subjects, repeated-measures design. After obtaining the baseline physiological measures (no music), the participant will be exposed to relaxing music and then fast upbeat music. We will compare the impact of music genre on the human stress response. Findings on the impact of music genre on the stress response can provide insight on potential ways manage stress.

POSTER: SOCIAL SCIENCES

And How Does That Make You Feel? The Importance of Mental Health Conversations Among Elementary School Students in Upper-Grade Levels and Their Parents

Denisse Zepeda

Salt Lake Community College

As adults, we decide whether or not we get help to address our mental health concerns, but what about those who are vulnerable and dependent on us, like the children in our lives? How are we helping children understand and navigate their emotions in this tumultuous world? Are conversations about emotions being held at home or are they yet another task for their teachers at school? How does having mental health conversations between elementary school students in upper-grade levels and their parents affect their academic performance? The purpose of this study is to investigate whether having mental health conversations between elementary school children and their parents affects their academic performance. The study included 88 students in grades 4–6 (9–12 years of age) from a public school in a city of Utah, United States. Because students this age are a vulnerable population, participation in this study was restricted to those with parental approval. A survey was

implemented during two weeks in November and December 2022. The results showed that having mental health conversations at home positively impacts student's academic performance.

POSTER: SOCIAL SCIENCES

Does Combat Experience Affect One's Religious Beliefs?

Allye Baker

Salt Lake Community College

Does military combat affect one's spiritual beliefs? Are people who experience combat more likely to use their faith as a means of coping, or are they more likely to abandon or question their beliefs? Previous studies have shown that religion helps with the trauma that goes with experiencing combat, but an individual's faith is still negatively affected by it. With moral injury being common among active military personnel as well as veterans, it is important to understand how moral injury affects a person and how we can help mitigate and potentially prevent those effects. My methods in answering these questions were to examine various peer-reviewed journals about the subject as well as conducting a survey on three different social media platforms. There is a lot more research needed to be done regarding these matters to effectively say that combat has an impact on a person's religion, but through my surveys I found that most people were religious prior to joining the military experience and either had no changes in their beliefs or changes in their beliefs varying from the importance and frequency it held in their life to their actual ideologies, such as going from religious to spiritual.

POSTER: SOCIAL SCIENCES

The Aftermath of Rape

Adyson LeeMaster

Brigham Young University

Certain characteristics of rape affect the likelihood that a survivor will develop post-traumatic stress disorder (PTSD); those researched in this literature review include intoxication at the time of the rape, whether or not the survivor knew the perpetrator, and if the perpetrator used a

weapon. It was found that intoxication at the time of the rape increased the likelihood that the survivor would develop chronic PTSD; the survivor knowing the perpetrator increased the percentage of development of PTSD; and the perpetrator using a weapon also increased the likelihood that the survivor would develop PTSD. It is also discussed the extent to which PTSD affects the survivors biologically, sociologically, and psychologically.

POSTER: SOCIAL SCIENCES

Insecure Attachment: Predictor of Antisocial Personality Disorder

Maria Balaceanu, Alyssa English, Dannelle Larsen-Rife, Ed Wu, Grace Carsey, Ives Hong, Rosemary Mwithiga, Youssef Harraq, and Tara Caplin

Utah Tech University

There is an association between attachment styles formed in childhood and behaviors and relationships experienced in adulthood. The attachment one develops through the childhood years will impact how he perceives and understands the world surrounding him. Insecure attachment is associated with antisocial behaviors and characteristics, which start displaying as early as childhood years. One important cause of insecure attachment is neglectful and callous caregiving. The lack of positive, emotional involvement of primary caregivers reinforces antisocial behaviors in children. The care children are attended with has a crucial impact on the child's development. Personality disorder traits start developing in childhood. During the first 18 months of life, the quality of the parent-child relationship can predict whether a child will display antisocial behaviors later in life. If the primary caregiver displays emotional unavailability, the child will be left without the tools needed to properly process and regulate emotions, such as stress. If the child is deprived of these crucial skills, his development can be endangered. The child becomes prone to develop disorganized attachment. The mother-child relationship is of utmost importance, and when the child's emotions and needs are misunderstood and neglected, it can cause the child distress. The child will have a hard time developing a healthy stress control system. The feeling of disconnect between the mother and child can negatively impact the child long-term, causing attachment difficulties, which can further lead to psychiatric disorders in adulthood. This paper focuses on insecure attachment and the negative impact it has

on an individual's behaviors and interpersonal relationships in adulthood. This paper includes several research studies demonstrating a connection between insecure attachment and behavioral and relational issues.

POSTER: SOCIAL SCIENCES

The Attachment Doula Dynamic: A Mediation Analysis of Pain Management During Labor and Delivery

Grace Carsey, Dannelle Larsen-Rife, Ed Wu, Alyssa English, Youssef Harraq, Rosemary Mwithiga, Miles Yablonovsky Ives Hong, Tara Caplin, Jake Leaverton, Hunter Mitchell, and Maria Balaceanu

Utah Tech University

Inadequate pain management during labor and delivery may be traumatic and can contribute to the development of negative maternal and neonatal health outcomes. Infants of mothers who reported unmanaged pain during labor and delivery were more likely to have lower Apgar scores. The presence of a doula during labor and delivery seems to have positive effects on both the mother and infant and is associated with lower rates of cesarean section and decreased use of pain medication. The relationship between attachment and pain perception during labor and delivery is also well-documented. However, the relationship between attachment style, the presence of a doula, and pain management during childbirth is not well understood. Research suggests that individuals with avoidant attachment styles avoid seeking support and have difficulty expressing their emotions. Therefore, it is possible avoidant attachment styles may feel uncomfortable with the close physical and emotional support provided by doulas. This additional stress may influence pain perception during labor and delivery. Conversely, those with anxious attachment styles tend to seek excessive social support, thus the presence of a doula may have a positive impact on pain management. Participants (N=136) reported on their first birth, their adult attachment anxiety and avoidance using the Relationship Structures Questionnaire (ECR-RS), and pain experienced during labor and delivery. Mediation analysis and regression models will be conducted to determine if attachment mediates the influence of doula presence on pain during labor and delivery. Findings from this study may have implications for individualized care and in the prevention of traumatic obstetric experiences related to pain, and the associated negative maternal and neonatal outcomes.

POSTER: SOCIAL SCIENCES

Understanding Drug-Related Harm Reduction Practices

Ellie Llewelyn

Utah Valley University

This research study is intended to identify the impact of drug-related harm reduction on public health in the state of Utah. Harm reduction focuses on unbiased compassion for those struggling with addiction. Harm reduction provides drug users with safe resources to replace other harmful means of drug administration that may result in negative health effects. I have been studying the harm reduction resources currently in place and how they compare with those in other states using secondary data analysis. The goal of this analysis is to better understand the positive and negative influences of harm reduction resulting from addictive behavior. As a part of this analysis, I will explain the laws and restrictions on harm reduction for drug users. I will also include examples of harm reduction methods used today.

POSTER: SOCIAL SCIENCES

What Values Are Preferred in a Potential Mate, and Which Values Are a Deal Breaker When Absent?

Sydney Muller, Adrienne Shelley, Aftyn Marker, Corbyn Anderson, Tristan Heber, Breana Barson, and Breana Bailey

Snow College

This study investigates what people look for in both short-term and long-term partners, what traits are most important, why people may have these preferences, and which traits people are willing to overlook. We are going to look at which values people most desire, and which values are a deal breaker when not apparent. In today's generation, dating seems to be the biggest struggle. People struggle with the thoughts of "Why do my relationships always fail?" and "Why am I so undesirable?" By doing this research, we hope to help answer some of those questions. Some variables we are going to look at include: religion, gender, political party, short-term vs long-term relationships, and parents' relationship to each other throughout their childhood. To maximize the effectiveness of our research, we plan to send out a survey via link and QR code to any

willing participants between the ages of 18 and 25 years. Our research is based on a past research done by Professor David Buss in 1985 (*Am Sci* 73, 47-51) on human mate selection. Buss stated, “Opposites are sometimes said to attract, but in fact we are likely to marry someone who is similar to us in almost every variable.” Although that study was done more than 30 years ago, we believe that there are some findings that still hold true in our generation today. However, there are some things Buss found that we believe may be different as well. We believe that because of the secluded culture we are surrounded by, people may value having similar religious and political beliefs more than someone who is kind and understanding as Buss found. Because our study is a new establishment, we will require more research before we can draw any conclusions.

POSTER: SOCIAL SCIENCES

Understanding Us - Street Tai Chi

Kassidy Drage, Luis Valentan, Francesco Vales

Salt Lake Community College

Understanding Us is a non-profit organization that provides several programs focusing on individuals experiencing homelessness. They currently run a Tai Chi program three days a week at an outdoor public location. The organization has asked student researchers to collect and analyze data about program participants. We have gathered preliminary demographic survey data to help the organization better understand the population they are serving and meet the needs of participants. To date, we have collected around 100 responses. In addition to the demographic survey data, we have also included anecdotal examples and interview responses from participants in the Street Tai Chi program.

POSTER: SOCIAL SCIENCES

Women, Weight, and the Workplace

Niko Dawson (Mentor: Dr. Brandon Koford)

Weber State University

Extensive effort has gone into researching the gender pay gap and what forces could be responsible for this societal disadvantage. Meanwhile, studies have shown an overall negative relationship between income and

resulting weight, concluding that obesity rates are higher at lower levels of income. However, not much research has been conducted to analyze whether the causality runs in the reverse direction: perhaps weight bias at the workplace causes lower incomes among heavier people. Using the most recent quantitative data from the National Health and Nutrition Examination Survey, this research uses an interval regression model of income on weight with additional control variables to examine the effect of weight bias on income for men and women, finding that for women, excess weight decreases annual household income.

POSTER: SOCIAL SCIENCES

Exploring the Prevalence and Determinants of Academic Dishonesty among College Students: A Survey Study

Jay Berry, Tiana Stanley, and Valeria Perdomo

Snow College

Academic dishonesty, a popular trend among college students, has taken many forms through the decades. Anton Skshidlevsky mentions in his article on ProctorEdu “According to a survey conducted by the CollegeHumor website, among 30,000 respondents, 60.8% of college students admitted to committing some form of cheating. Moreover, 16.5% of them didn’t feel guilty about it” (2022, <https://proctoredu.com/blog/tpost/5dk67zrns1-academic-dishonesty-statistics>). More recently, it has taken the form of e-cheating (electronic cheating) through websites such as ChatGPT, Quizlet, and simple Google searches. Although this has professors concerned about the future of education, modern problems require modern solutions. There are websites designed to prevent e-cheating through similar electronic means like Turnitin, Proctorio, Testing Center, Oral tests, and Lockdown Browsers. However, the use of electronics in the classroom is becoming more and more a part of the education system. With these changes and the exposure that upcoming generations have to electronics, new rules may need to be set to keep students away from the temptations of academic cheating. What do college students consider to be academic cheating (fraud, plagiarism)? Can academic dishonesty be justifiable? What kinds of measures are appropriate in preventing academic dishonesty? Specifically, the research question we would like to explore would be: What is academic dishonesty (fraud, plagiarism), and can it be justifiable? To conduct this study on the frequency, reasoning, and ways

of academic dishonesty, we will be administering a series of surveys among the Snow College population, asking students and professors what academic dishonesty is, if they've participated in academic dishonesty, if they've seen academic dishonesty, and if they think it can be justified. Along with that, we'll be presenting scenarios in which academic dishonesty has taken place, and discover how they react to the given situations.

SOCIAL SCIENCES

Staring Into the Abyss: The Origins of Serial Killer Behavior

Peyton Kosman

University of Utah

The term "psychopath" was first coined in the late 19th century, but it was not until at least the middle to late 20th century that tangible progress was made in understanding this type of distinct personality. In particular, behavioral investigative units were created to study, categorize, and profile such individuals. This paper is first an exploration of the term "psychopath" as it has evolved in the 20th century with the creation of the DSM psychiatric evaluative tool, the establishment of the Behavioral Science Unit, and the development of actual profiling techniques for apprehending psychopathic killers. In addition, this study will focus on the origins of psychopathic behavior, specifically the behavior of serial killers. Using grounded theory, the study will examine the histories of specific serial killers across multiple decades to help construct a theory of the origins of serial killer behavior.

SOCIAL SCIENCES

Rising Irreligion in the Beehive State: Why Disaffected Latter-day Saints in Utah are More Likely to Abandon Religion than Switch Denominations

Rick Phillips

University of North Florida

The percentage of people in Utah with no religious affiliation has increased rapidly in the 21st century. Many of these Utahns are former

members of The Church of Jesus Christ of Latter-day Saints (the LDS, or Mormon, church). Studies show that when Mormons abandon their faith they are less likely than other Christians to switch to a different denomination. Rather, they tend to forsake organized religion entirely. This paper uses both quantitative data and ethnographic interviews collected along the Wasatch Front to explore the underlying reasons for this pattern of Mormon disaffiliation. Findings reveal that aspects of Mormon theology, the perceived political alignment of the church, and the structure of LDS social networks make switching to a different denomination difficult for disaffected Mormons. The paper shows how the factors contributing to Mormon disaffiliation are more pronounced in Utah, where Mormons make up the majority of the population than in other places where Mormons are typically a small minority.

SOCIAL SCIENCES

Recovery Support Services in Substance Use Treatment Completion

Brett Bartruff

University of Pennsylvania

This study aims to understand the relationship between recovery support services provided by certified peers and clients' length of time in and completion of substance use treatment. Responses to enhance treatment engagement include recovery support programs staffed by people with lived experience of substance use and recovery; however, research in this area is limited. This study involves an archival chart review from a western state's community mental health agency with a total sample of 1,007. To test treatment effects across groups, an independent sample t-test was used to test the difference in length of treatment, and a chi-square test of independence was used to examine treatment completion. Additionally, to test treatment effects across peer services groups, two hierarchical regression analyses were used to test the predictive value of peer services on length of stay in treatment and treatment completion. To test treatment effects in the peer-services group, multivariable regression analysis was used to test two models, one for each dependent variable. This study's initial treatment effect testing finds that people who received any recovery support service stayed in substance use treatment for more days. However, the additional hierarchical regression analysis finds that when controlling for demographic and clinical characteristic covariates, there was no statistically significant difference in treatment

length between people who received peer services and the comparison group. Among people who received recovery support services, each additional session with a peer worker predicted an 11% increase in the likelihood of completing treatment. The additional findings of the post hoc analysis include the number of different kinds of peer services provided, years of education, and workforce participation as predictors of both dependent variables in the peer services group. The number of previous treatment episodes also had a statistically significant positive association with increased days in treatment for the peer services group.

SOCIAL SCIENCES

Using Facebook and Reddit to Code Support Group Member Posts: What We Can Learn about the Needs of Patients with Postural Orthostatic Tachycardia Syndrome

April Law

Utah Valley University

Many patients with chronic illnesses feel that they lack resources when it comes to finding knowledgeable specialists, helpful consumer products, and support for loved ones. This research project aims to bridge the gaps of understanding between patients and their families and medical professionals by observing common patient complaints and requests for advice on social media platforms. By coding these responses and looking for commonalities, manufacturers may also benefit by learning to create better products that serve the needs of chronically ill patients. Similar studies have been performed for other areas of research. A social media study was conducted in Canada to determine social levels of hesitancy toward COVID-19 vaccines (Rotolo et al., 2022, *Vaccine* 40, 2790-2796). Most Canadian citizens have been vaccinated, and researchers believe that the results of this study can help guide educational attempts for unvaccinated citizens. Perry and Park (2021, 2021 IEEE 9th International Conference on Healthcare Informatics) performed a qualitative analysis of Twitter feeds to search for major themes of suicidality and found that while intrapersonal and interpersonal factors were amply expressed, about half of the tweets expressed suicidality when discussing social issues such as health and politics. This study compares posts from Facebook and Reddit to search for commonalities among patients in support groups for postural orthostatic tachycardia syndrome (POTS). After posts are qualitatively

coded, a statistical analysis is performed. By discovering the most discussed support group topics, doctors, manufacturers, content creators, and loved ones can better understand the needs of patients with POTS.

SOCIAL SCIENCES

Pedestrian Safety at Night: A Case Study of Public Space Lighting

Sabrina Waite and Jamie Spinney

Southern Utah University

Sidewalks are a fundamental and necessary part of public space, but it is becoming increasingly dangerous to be a pedestrian, especially at night. The primary purpose of this study was to perform an audit of sidewalk and intersection illuminance in the neighborhoods immediately surrounding the campus of Southern Utah University in Cedar City, Utah. A secondary purpose was to compare measured illuminance values with a generally accepted illumination standard. A digital light meter was used to measure illuminance at street intersections and regularly spaced mid-block locations. GPS coordinates were also collected to enable mapping and spatial analysis of the illuminance data. Results suggest the pedestrian environment lacks uniformity and most sample observations fail to meet the minimum illumination standards, which means the study area poses significant pedestrian safety and security concerns, because it is too dark at night. Results also provide the information required for targeted visibility enhancements of both sidewalks and crosswalks in the study area.

SOCIAL SCIENCES

Sisters in Struggle: The Resistance of Women in Hip Hop

Theresa A. Martinez

University of Utah

Women have played an integral role in all manifestations of hip hop culture from its roots in the 1970s to the present, including breakdancing and graffiti, but particularly rap music. In fact, women rappers have shaped the genre from the very beginning. In particular, while rap music

has continued to serve as a reflection on and weighty culture critique of profound disparities facing African Americans and other people of color in America, it has also offered insights into the lives of Black women. In this regard, the lived experiences of Black women surviving within this context have been echoed in the voices of women hip hop artists who reflect on everything from misogyny to domestic violence to social justice. This paper focuses on a lyrical and thematic analysis of the work of four women hip hop artists, two legendary hip hop artists who emerged in the late 1980s and two contemporary hip hop artists who are already making a mark on the genre as they communicate and reflect on their sociohistorical context. The thematic and lyrical analysis of our four hip hop artists will be unpacked through a theoretical lens that draws on oppositional cultures or cultures of resistance within the foundation of a Black women's standpoint voices of resistance to intersecting oppressions in their time.

SOCIAL SCIENCES

From “Model Minority” to “Model Targets”

Huiying Hill

Weber State University

With the nationwide protests about “Black Lives Matter,” subjects of racial/ethnic relations in the United States once again are brought to the forefront. One major reason is that we as a nation have never thoroughly and seriously deal with racial problems once and for all. This paper will examine another minority group, Asian Americans, and their experience in this racist American social structural and cultural environment. Asian Americans have been labeled as a “model minority” because of some of the subgroups’ high educational and economic achievements in the past few decades. But, they still suffer racial discrimination and prejudice in different forms than that of African Americans. Especially after the COVID-19 spread to the United States, violence and physical assaults against Asian, especially East Asian, Americans are sky rocketed. The author conducted a survey and some interviews among Asian Americans, most of whom are Chinese American, to get a better grasp of the types and forms of prejudice and discrimination experienced by them and their children. The main purpose is to find out what is the fundamental underline reason that minority groups are still facing so much prejudice and discrimination in the United States.

SOCIAL SCIENCES

Profiling Characteristics of Gun Violence in the Intermountain West Area

Daniel Kim and Yong Seog Kim

Utah State University

In this paper, we aimed to identify the unique characteristics observed in gun violence incident data sets collected during the period of 2014–2017 in the Intermountain West compared with other states in the United States. We first compare the temporal characteristics in terms of weekdays, monthly, and yearly patterns of gun violence incidents in two regions. Then we identify the differences in demographic characteristics in age and gender of participants involved in gun violence incidents from two regions. Finally, we like to take societal perspectives through crime rate, strictness of firearm registration requirements, and the index of drug and alcohol use with the hope of identifying differences in their relationship with gun violence incidents between two regions.

SOCIAL SCIENCES

Internalized Stigmas: Public Transit and the Tragedy of Preconception

Lizzie Jensen

Utah State University

Each day, the Cache Valley Transit District (CVTD) coordinates roughly 4,300 rides. In a community with over 100,000 residents, including 28,000 students, these rides represent less than 3% of daily commutes. Unfortunately, while transportation is a basic need, decades of stigmatization have made economical forms, like public transit systems, less popular. In the United States, public transit has become heavily stigmatized due to perceptions people have about the role federally funded transit systems like bus programs have in society. Many people in both urban and rural areas perceive bus systems with disdain. They are interpreted as unclean, unsafe, and only for people who cannot afford cars. To this extent, internalized stigmas impact the efficacy and usability of public transit in a wide variety of communities. In the Cache Valley, the free bus systems are underutilized by residents and students alike, as they are influenced by unconscious prejudices. Although it may

seem that factors like cleanliness, convenience, cost, and safety would be the main contributors to poor public transit usage, it generally is caused by much broader ideas and themes, including historical segregation, class distinctions and stereotypes, political mismanagement, convenience/timeliness, and cost. The complexity of the issue makes it difficult to approach and resolve on a universal level. Because of this, humans have an obligation to examine their judgments on public transit and evaluate whether or not utilizing available transit sources, like the CVTD, is a good move for them on an individual level. Reducing the emissions of unnecessary vehicles on the road is a critical aspect of sustainability. Reevaluating internalized stigmas can contribute to increasing the quality of life in communities, and help improve the experience of those who already rely on public transit. This essay dissects and diagnoses such issues.

SOCIAL SCIENCES

Perceptions of Water Use at Weber State University

Zoey Krumroy

Weber State University

Weber State University (WSU) is known for its work in energy conservation, but with growing concern and uncertainty of Utah's water resources, there is more interest in what WSU can be doing. This research explores WSU stakeholders' attitudes, beliefs, and perceptions on water use and water conservation in Utah and participtionally here at WSU. This enhances the knowledge for facilities management, the Energy and Sustainability Office, and administrators to better serve campus needs and increase water sustainability. Nine focus groups and five one-on-one interviews were conducted. Participants included a variety of WSU faculty members, staff, students, and administrators from different disciplines and locations. Many participants value water greatly and expressed concern for the coming years, especially because of prolonged droughts and population growth. As a result, participants feel all of Utah, as well as WSU, should be doing more to conserve water—from better technology inside buildings, to the landscape outside, to a change in how water is viewed. Their suggestions reveal that many participants are not aware of what WSU is already doing and is planning to do in terms of water conservation. So, although WSU stakeholders are interested and concerned with WSU water use, their engagement with what WSU is doing with water does not match their

concerns. This disconnect demonstrates a need for WSU to improve its work to increase awareness and knowledge about campus water conservation, as well as for stakeholders to increase their involvement and participation in these efforts.

SOCIAL SCIENCES

Increase of Pain Sensitivity and Anxiety

Hunter Mitchell

Utah Tech University

Pain is a strong and necessary feeling that triggers a signal for the body to respond to uncomfortable stimuli. This negative effect works along with fear and anxiety to provide protection against potential threats. Pain and anxiety are critical elements of not only early development but adulthood as well. In this study, we examine anxiety, depression, and pain sensitivity to determine whether pain is felt equally among people with certain mental health challenges. We hypothesized a correlation with anxiety and increased pain sensitivity. Our sample contained 308 participants with a mean \pm SD age of 31.77 \pm 15.27 years; of these participants 77% were female. We sampled from a diverse background, recruiting by use of fliers, social media, and word of mouth. Each participant filled out an online questionnaire, taking about 60 minutes to complete it. After completion, we ran the appropriate statistical analysis to determine a correlation using SPSS. The results showed a statistically significant correlation between increased pain sensitivity and anxiety and a trend between decreased pain sensitivity and depression. We discuss the possible implications of the findings and the need for future research to be done in this area.