

The Journal of the
**Utah Academy of
Sciences, Arts, & Letters**
Volume 95 • 2018

**Includes selected and refereed articles from the
2018 Annual Conference
held at
Southern Utah University
April 7, 2018**

Editor
Kristin L. Kraus

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ISBN-13: 978-0-9988268-2-0

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Cover Photo: “The Baton Rouge” from *Life on the Mississippi* by Mark Twain. See Todd Goddard, “Mark Twain’s Geographic Imagination in *Life on the Mississippi*,” p. 185.

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 *Encyclia*. 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.

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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.

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The Journal of the
**Utah Academy of
Sciences, Arts, & Letters—2018**

AWARDS

Distinguished Service Award	11
Academy Fellow 2019	12
O.C. Tanner Lecture	14
John and Olga Gardner Prize	15
Honorary Member 2019	16
2018 Best Paper Awards	17

ARTICLES

BIOLOGICAL SCIENCES

Microbial Degradation of Art-Waste Solvents	19
Gabriel McKay, Craig Oberg, Michele Culumber, Edward Walker, and Matthew Domek, <i>Weber State University</i>	
Double-crested Cormorants Respond to Fish Stocking of Rainbow Trout in Suburban Ponds in Northern Utah	31
Nicholas Padilla, John Kendrick, Garrett Evans, Jantz Arbon, Carl Catalan, and Austin White, <i>Weber State University</i>	

BUSINESS

How Early Profitability Index Can Predict Bank Failure: Evidence from U.S. Bank Failure during 2008–2010	43
Abdus Samad, <i>Utah Valley University</i>	

EDUCATION

Educator Ethic Laws Across the United States 57

Shirley Dawson,¹ Bonnie Hofland,¹ Marjorie Lynes,² and Richard Squire³

¹Weber State University; ²University of Utah; ³Snow College

ENGINEERING

Measuring Solar Flux and Absorptivity 75

David J. Armijo, Ali Siahpush, and Logan D. Evans,
Southern Utah University

Simple Experimental, Analytical, and Numerical Methods to Evaluate the Deflection of a Beam 89

Jacob Carter and Ali Siahpush, *Southern Utah University*

A Simple Steady-State Experimental Method to Determine the Thermal Conductivity of Solid Plate 99

Jacob W. Carter, Justin C. Christensen, and Ali S. Siahpush,
Southern Utah University

Measuring the Thermal Conductivity of Air 117

Christian Hamilton, Casey Cooper, and Ali Siahpush, *Utah State University*

Creating a Phase Change Thermal Energy Measurement System (Part 1: Design and Construction) 133

Daniel C. Ulrich, Ben C. Thrift, and Ali Siahpush, *Utah State University*

Airglow Measurements from the SABER/TIMED Satellite 153

Brian J. Simons,¹ Doran J. Baker,¹ Gene A. Ware,¹ Martin G. Mlynczak,² and James M. Russell III³

¹Utah State University, ²NASA Langley Research, and ³Hampton University

EXERCISE SCIENCE AND OUTDOOR RECREATION

- Gender Differences in the Role of Acculturation, Self-Regulation, and Self-Esteem in Alcohol Consumption among Asian American Adults** 161

Yan Huang, *Weber State University*

- Unique Rituals, Pre-Performance Routines and Superstitious Behavior used by Elite Senior Athletes** 179

M. Vinson Miner and T. Cole Parkinson, *Utah Valley University*

LETTERS—LANGUAGE & LITERATURE

- Mark Twain's Geographic Imagination in *Life on the Mississippi*** 185

Todd Goddard, *Utah Valley University*

PHYSICAL SCIENCES

- Probing Particle-Wave Duality with the Stern-Gerlach Effect** 203

Richard D. Barney and Jean-François S. Van Huele, *Brigham Young University*

- The Mathematics of Mario Party 10** 215

Andrew Misseldine, *Southern Utah University*

- A Diffusion-Limited Titration Using Microfluidics** 235

Jaxon Barney, Tyson Torgersen, and Christopher F. Monson, *Southern Utah University*

- The Effects of Radio Jet Feedback on Star Formation in Satellite Galaxies** 251

Taylor Hammack, Kasen Lisonbee, Bryan May, Jordan Memmott, Kallin Raymond, Morgan Taylor, and Cameron Pace, *Southern Utah University*

- Using Exoplanet Transits to Characterize the Great Basin Observatory** 263

Katherine Wilcox and Rhett Zollinger, *Southern Utah University*

SOCIAL SCIENCES

- Dark Sky Compliance: Measuring the Effectiveness of
Outdoor Lighting Ordinances in Ogden Valley** 271

Jeremy Bryson and Amanda Cooley, *Weber State University*

- Law is Politics: Why Critical Legal Studies, Critical Race
Theory, and Other Critical Legal Disciplines Must Reunite** 281

W. Scott Jackson, *Snow College*

- The Process of Sanctification: A Bourdieusian Approach
to the Declension of Power in New England Puritan Clergy** 297

W. Scott Jackson, *Snow College*

- Demography and Information Technology Affect Religious
Commitment among Latter-day Saints in Utah and the
Intermountain West** 317

Rick Phillips, *University of North Florida*

- Thereby Throw Sand: Presidential Media Respect through
Honorific. References in White House Press Briefings,
2001-2017** 333

Thomas C. Terry, *Utah State University*

- ABSTRACTS** 347

DISTINGUISHED SERVICE AWARD

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

Bonnie K. Baxter, PhD

Great Salt Lake Institute and Westminster College

Dr. Bonnie K. Baxter is Director of the Great Salt Lake Institute and Professor of Biology at Westminster College in Salt Lake City, Utah. She has been studying the microbial communities of Great Salt Lake for two decades, applying her background in cellular biochemistry to the physiology of halophilic archaea, which dominate in the lake's saltiest brines. This expertise has led to many discoveries relating to DNA damage and repair mechanisms, carotenoid photobiology, microbial diversity, and the relationship of this lake to Mars. In 2008, Baxter and colleagues created Great Salt Lake Institute, which serves to enhance research, education, and stewardship of Great Salt Lake. Through this non-profit organization, the institute pulls together Westminster undergraduates and researchers from all around the world to study this unique ecosystem and share their discoveries. She is also dedicated to integration of research in undergraduate science education and to outreach efforts that inspire learning and stewardship. She obtained her Ph.D. in Genetics at the University of North Carolina, Chapel Hill, and did her post-doctoral research in the Department of Biochemistry and Biophysics at Washington State University.

ACADEMY FELLOW 2019

R. Steve Turley, PhD, and Deon Turley, BS

R. Steven Turley is a professor of physics at Brigham Young University, where he has also served as a Department Chair, an Associate Dean, and Co-Chair of the BYU Faculty Advisement Committee. He is currently serving as a temporary Program Director at the National Science Foundation. He received his BS in physics from Brigham Young University, Summa Cum Laude and with Highest Honors. He received a PhD in Physics from the Massachusetts Institute of Technology in physics, where he was a Howard Hughes Doctoral Fellow. Before coming to BYU, Steve worked as a Senior Member of the Technical Staff at Hughes Research Labs. His current research is in extreme ultraviolet optics. He has authored 73 refereed journal articles and four book chapters and holds one patent. Seventeen of his publications have been in the Journal of the Utah Academy of Sciences, Arts and Letters. Twenty-two of his 108 presentations, including his first as an undergraduate student were at Utah Academy meetings. He is a Fellow of the American Association of Physics Teachers and received the Karl G. Maeser General Education Professorship and Alcuin Fellowship from Brigham Young University. He has been on the board of the Utah Academy since 2001, serving as President, Chair of the Division of Physical Sciences, Webmaster, and Poster Session Chair. He has also served as an Associate Affiliate Director of the Utah Space Grant Consortium, Treasurer of the American Association of Physics Teachers, Co-PI of the national Physics New Faculty Workshop, and on the Education Committee of the American Association of Physics Teachers.

Deon Turley served as secretary to the Utah Academy of Sciences, Arts, and Letters during the years that Steve Turley served as its president, 2005–2008. Deon graduated from BYU with a BS in Mathematics. After her marriage, she chose to focus on raising a family and contributing to her community with volunteer service. PTA provided a good nexus for her interests in children and education. She served at school, district, and state levels of PTA organization. During her years on the Utah PTA board, she served as Family Life Commissioner, Education Commissioner, and a member of the Bylaws Committee. She also served as secretary to the Utah Education Coalition, a coalition of leaders from such associations as the UEA, Utah Superintendents Association, classified employees association, the State Superintendent and members of the State School Board, as well as a representative of the Utah Council of Education Deans. When she was invited to serve as

secretary for Utah Academy, she found that the bylaws for the organization were severely outdated. She drafted and proposed a new set of bylaws and standing rules that better reflected current practices of the Academy. Deon also worked on the Centennial events for the Academy in 2008, including drafting and submitting a proclamation to Governor Huntsman recognizing our centennial anniversary, which he accepted and made. Since the end of her term as secretary, Deon has served on the Provo City Transportation Committee and on the Planning Commission. However, she treasures her association with the Academy Board members and the events they planned. She hopes to volunteer when needed in future conferences or events.

O.C. TANNER LECTURE

“Salt of the Earth: Interdisciplinary Learning with the Great Salt Lake Institute”

Bonnie K. Baxter, PhD

Great Salt Lake Institute and Westminster College

Utah's immense terminal lake has inspired exploration since humans first inhabited the valley thousands of years ago. Indeed, Great Salt Lake has been the subject of poetry, a site for land art, and a system for scientific investigation. Ten years ago, we established the Great Salt Lake Institute at Westminster College to connect people to the lake through research and education. Our role is supporting creative work on Great Salt Lake and facilitating discovery, and our strength is in the partnerships we build. In this last year alone, we have: 1) placed a “PELI-cam” on Gunnison Island, which can bring an off-limits wildlife habitat to the classroom, 2) begun a science/art integrated undergraduate research program, 3) held public meetings to prevent a landfill operation on the shores of Great Salt Lake, 4) collected oral histories of duck hunters, and 5) collaborated with ANSA on Great Salt Lake as a Martian analogue. This talk will present a model for building an interdisciplinary center for learning in an undergraduate environment.

JOHN & OLGA GARDNER PRIZE

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

Jody Rosenblatt, PhD

University of Utah

Jody Rosenblatt is Professor of Oncological Sciences at the University of Utah and Investigator at the Huntsman Cancer Institute. During her PhD at the University of California, San Francisco, with Dr. Timothy Mitchison, she studied actin filament turnover, and as a post-doc at the MRC-LMCB at University College London, she discovered epithelial cell extrusion, a process that eliminates dying cells without forming any gaps. Her lab studies how epithelia maintain constant cell numbers through cell death and cell division, and they have found that mechanical forces control each process. When cells become too crowded, they extrude some cells that later die, and when cells are too sparse, stretch activates cells to rapidly divide. Surprisingly, both opposing processes require the same stretch-activated calcium channel, Piezo1, depending on the force encountered. Extrusion is critical for regulating epithelial cell number, as they find that aggressive metastatic cancers and asthma can result from defective extrusion signaling. Understanding the basic cell biology of cell death is now revealing new etiologies for diseases that currently lack treatments. We believe that understanding the roots of a disease will better pave the way to finding its cure, rather than merely managing its symptoms.

HONORARY MEMBER 2019

Brian Kershishnik, MFA

Brian Kershishnik is the youngest of a happy and widely traveled family of sons. His father's work as a petroleum geologist took them to various continents across the globe where his mother unfailingly set up a home filled with music, great food, and active conversation, furnished with treasures and artifacts from their travels and hosting frequent parties and exotic slide shows of their globetrotting family life. Brian grew up happily dividing his time between his dad's overseas assignments and summers spent with cousins in Rock Springs, Wyoming, a friendly, curious kid and with no notion at all of what he wanted to be when he grew up. Although he drew often to entertain himself, it never occurred to him that people actually did that for a living. Finding himself unceremoniously graduated from high school after an emergency evacuation from Pakistan abruptly ended his senior year, he applied to the University of Utah, where his brother was attending school. A General Architecture class from Peter Goss and a ceramics class from Dorothy Bearnsen began to focus his interests. After serving as a missionary in Northern Europe, he determined to study ceramics at Brigham Young University and then architecture at the University of Utah. During his first year in ceramics, he met Joe and Lee Bennion and arranged to spend the summer working in Joe's pottery. After some months, it became apparent that Brian was no potter, and Lee suggested he try something with her paint box. Painting changed everything. Gallery owner Dolores Chase noticed his exhibitions and offered to begin his professional career. While based in Utah, Brian is reaching ever-widening audiences with the expansion of a national base of collectors and shows, as well as works featured in collections around the world. However widely he wanders, his yearly openings at David Ericson Fine Art in Salt Lake City and Meyer Gallery in Park City always have an air of reunion and camaraderie. His studio practice shifts between monastic solitude in his rural Kanosh studio and communal busy-ness in his Provo studio. He now lives with his wife, Faith, their dog and their bees, in the town of Provo, surrounded by his three grown children.

2018 BEST PAPER AWARDS

Business

How Early Profitability Index Can Predict Bank Failure: Evidence from U.S. Bank Failure during 2008-2010

Abdus Samad

Utah Valley University

Education

The State of Educator Ethics Laws in the United States

Shirley Dawson,¹ Bonnie Hofland,¹ Marjorie Lynes,² Richard Squire³

¹Weber State University, ²University of Utah, ³Snow College

Engineering

Creating a Phase Change Thermal Energy Measurement System

Daniel C. Ulrich, Ben C. Thrift, Ali Siahpush

Southern Utah University

Exercise Science and Outdoor Education

Gender Differences in the Role of Acculturation, Self-Regulation, and Self-Esteem in Alcohol Consumption among Asian American Adults

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Utah Valley University

Physical Sciences

Probing the Particle-Wave Duality with the Stern-Gerlach Effect

Richard Barney, Jean-Francois S. Van Huele
Brigham Young University

Social Science

Demography and Information Technology Affect Religious Commitment among Latter-day Saints in Utah and the Intermountain West

Rick Phillips
University of North Florida

Microbial Degradation of Art-Waste Solvents

**Gabriel McKay, Craig Oberg, Michele Culumber,
Edward Walker, and Matthew Domek**

Weber State University

ABSTRACT

*Paints and solvents used in both acrylic and oil painting generate wastes resistant to decomposition, require expensive disposal fees, and pose a health hazard during storage. This waste represents a novel extreme microbial environment with a high concentration of organic solvents, metals, and pigments normally toxic or inhibitory to cell growth. In this study, microorganisms were isolated from paint waste storage containers, and the microbial degradation of three paint solvents (linseed oil, heptane, and turpenoid) by these bacterial isolates was investigated. All isolates were propagated in M9 minimal broth supplemented with a solvent. The majority of isolates formed biofilms at the solvent/broth interface after three weeks of incubation at 22°C. Using 16S rRNA sequencing, 10 isolates from paint waste containers were identified, including *Pseudomonas zhaocongensis*, *Planococcus citreus*, and *Planococcus riflettoensis*. Gas chromatography mass spectrometry (GC/MS) was used to measure microbial degradation of two solvents. GC/MS results indicated that six isolates degraded both heptane and oleic acid, a*

selected component of linseed oil, and metabolites were detected. Results show bacterial isolates from paint waste can degrade individual paint waste solvents.

INTRODUCTION

Art studios use paint and solvents requiring regulated disposal. Many paints contain metals like lead, arsenic, copper, and zinc, along with other heavy metals. Solvents commonly used in painting are often highly flammable, e.g., turpenoid, linseed oil, and heptane (Pratt Institute [n.d.]). These paints and solvents require specialized handling and disposal to minimize health hazards, environmental release, and fire danger. Art studios that use these paints and solvents are required by law to have toxic waste bins to hold these materials (EPA, 2017). Waste bins are periodically emptied, with their contents taken to hazardous waste disposal facilities. These chemicals are resistant to degradation under some environmental conditions, so they also require long-term storage. Art departments and studios use a variety of organic solvents of natural and synthetic origins including those examined in this study: turpenoid, linseed oil, and heptane.

Turpenoid is a less toxic alternative to turpentine that is primarily used for cleaning brushes and painting tools. It is sometimes referred to as “white spirits” and is preferred because it has a minimal odor and lower toxicity than turpentine (Weber Odorless MSDS, 2007). The composition of turpenoid solvents depends on the manufacturer, but it includes petroleum distillate that may contain aliphatic, alicyclic, and aromatic hydrocarbons (Larsen, 1996). Bioremediation in the environment would depend on a variety of growth conditions, but the chemicals in turpenoid would most likely be degraded by microorganisms via oxidative reactions and central metabolic pathways in aerobic environments (Marmulla and Harder, 2014).

Linseed oil is a combination of triglycerides extracted from flaxseeds that contains 55–60% α -linolenic acid (Gunstone et al., 1994). In a marsh bioremediation study, natural microbial consortia preferentially degraded the 18:3 ω 3 fatty acid into shorter fatty acids (Pereira et al., 2002). Although it is usually considered non-toxic and is commonly used as a “natural” wood varnish or sealant, “boiled” linseed oil used in art departments may be combined with metals such as cobalt and manganese (Klean-Strip MSDS, 2014) or other solvents that decrease the drying time (Gunstone, 1994). This also increases toxicity and impact on the environment. Upon drying, linseed oil polymerizes to form a solid. Linseed oil is highly flammable and can auto-ignite under aerobic conditions

when concentrated in wastes or on rags (Klean-Strip MSDS, 2014); therefore, linseed oil usually requires storage and disposal under anaerobic conditions.

Heptane is a seven-carbon straight chain alkane C_7H_{16} (National Center for Biotechnology Information, 2004). It is a highly flammable liquid and vapor (Heptane MSDS, 2018) and can cause skin irritation and may damage the eyes, central nervous system, and other organs if inhaled or ingested. Heptane is also highly toxic to aquatic life, but it is not highly soluble in water and does not persist long in aerobic environments.

Individually, or at low concentrations, these solvents are not of great environmental or other health concerns. However, in art departments they are used in high concentrations and may be combined with other materials including toxic metals. The combination of solvents, metals, and pigments in the waste containers creates a unique and extreme microbial habitat. To survive under these conditions, microorganisms must be adapted to tolerate high concentrations of organic solvents and to the pigments and metals present in the paints. The purpose of this project was to isolate and characterize microorganisms present in the waste containers used in the Weber State Department of Visual Art and Design's studios and to test the ability of these isolates to degrade some common solvents present in the containers.

MATERIALS AND METHODS

Isolation of Microorganisms from the Solvent Wastes

Samples for microbial isolation were taken from the paint and solvent waste collection containers in the Weber State University Department of Visual Art and Design using sterile swabs and collection containers. Samples from three waste containers were inoculated into six 250-ml flasks containing 100 ml of M9 minimal medium supplemented with turpenoid, heptane, or linseed oil at either 0.3 or 0.6% (v/v). Growth was compared with a noninoculated control flask of M9 medium. All seven flasks were incubated at 25°C with slow shaking for up to four weeks, until biofilms became visible on the sides of the flasks, primarily at the liquid/air interface (Fig. 1).



Figure 1. Enrichment of microorganisms from art waste containers. (Left) Left flask: control, no solvent added and not inoculated. Middle flask: 0.3% linseed oil, inoculated with biofilm from sample from art-waste container. Right flask: 0.6% linseed oil, inoculated with biofilm from sample from art-waste container. (Right) 1-5, Control, not inoculated; 1-6 and 1-3, growth on linseed oil, inoculated from enrichment flasks; 3A-1, growth of isolated colony on 3A-1 on linseed oil.

Biofilms from the enrichment flasks were sampled by aseptically transferring a small amount of the biofilm to a nutrient agar plate. Inoculated plates were incubated at 25°C for up to 14 d or until colonies appeared. Unique colonies were transferred again for isolation by the quadrant streak plate technique (Fig. 2). Individual isolates were grown at 25°C for 14 d. Isolates were examined for colony and cell morphology and Gram reaction (Table 1). Individual isolates were transferred to nutrient broth and incubated for 72 hours at 25°C for DNA analysis.

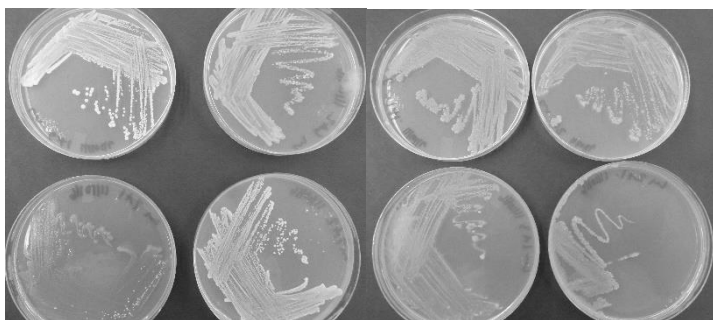


Figure 2. Examples of quadrant streak plates of isolates from the enrichment culture biofilms. Additional quadrant streaks were made when cultures were found to have multiple colony morphologies (not shown).

Table 1. Summary of colony morphology and Gram reaction of isolates selected for characterization and identification with 16S rRNA gene sequencing

Isolate	Colony Morphology	Gram Reaction	Blast Match
1A1	Irregular, umbonate, orange, rough	Negative, rod	na
1A2	Irregular, umbonate, tan, rough	Positive, rod	<i>Pseudomonas zhaodongensis</i> NEAU-ST5021 (100% identity)
1A3	Irregular, umbonate, tan, smooth	Positive, rod	<i>Pseudomonas zhaodongensis</i> NEAU-ST5021 (98% identity)
3A1	Irregular, umbonate, white, rough	Negative, rod	na
4A1	Irregular, umbonate, pink, rough	Negative, rod	na
5A1	Irregular, umbonate, tan, rough	Positive, rod	<i>Pseudomonas zhaodongensis</i> NEAU-ST502; (100% identity)
5A2	Irregular, convex, entire, orange, smooth	Positive, cocci	<i>Planococcus citreus</i> strain NBRC 15849 (98% identity) <i>Planococcus rifietoensis</i> strain M8 (98% identity)
6A1	Circular, raised, yellow, smooth	Positive, cocci	na
6A2	Circular, convex, orange	Positive, cocci	<i>Planococcus citreus</i> strain NBRC 15849 (98% identity) <i>Planococcus rifietoensis</i> strain M8 (98% identity)

na: not analyzed, failed sequencing

16S rRNA Gene Sequence Analysis

DNA was extracted from the individual isolates using the MoBio Ultra Clean Microbial DNA Extraction Kit (MoBio, Carlsbad, CA). The

16S rRNA gene was amplified using bacteria-specific primers (27F 5' AGA GTT TGA TCM TGG CTC AG 3'/1492R 5' ACG GYT ACC TTG TTA CGA CTT 3'). Amplifications were done in 25- μ l reactions with the 2X GoTaq Green Master Mix (Promega Corp, Madison, WI), 200 nM of each primer, and 2 μ l of the DNA template. Amplification parameters were 94°C for 3 min, followed by 25 cycles of 94°C for 45 s, 50°C for 1 min, 72°C for 2 min, with a final extension step at 72°C for 7 min. Sequencing was performed by the Idaho State University Molecular Research Core Facility (Pocatello, ID). Sequences were compared with the GenBank database using the nucleotide BLAST search tool (Madden, 2002).

Solvent Degradation by Selected Isolates

Individual isolates were inoculated into screw cap tubes containing M9 minimal medium broth with 0.2%, 0.6%, or 1.3% (v/v) of heptane or oleic acid for 14 d, and the tubes were sealed to reduce solvent evaporation. Gas chromatography mass-spectrometry (GC/MS) was used to determine which solvents were being broken down by different bacterial isolates. Heptane and oleic acid samples were analyzed by GC/MS directly without any derivatization. Peak areas and retention times for metabolite peaks were identified and compared with controls.

RESULTS

All of the samples collected from the WSU Department of Visual Art and Design waste containers demonstrated biofilm growth in M9 medium supplemented with heptane, turpenoid, or linseed oil at 0.3% and 0.6% concentrations. Many samples produced thick, colorful biofilms at the interface of the solvent and medium (Fig. 1 and Table 2). Individual isolates with diverse colony and cell morphologies were cultured from these biofilms (Fig. 2). Curiously, many of the isolates were pigmented bacteria. Characteristics of individual isolates selected for further analysis are summarized in Table 1.

Several of the isolates selected for sequencing yielded poor sequence results indicating mixed templates. Multiple attempts to isolate individual organisms were unsuccessful, suggesting a tightly bound consortium of at least two organisms may exist in the waste containers. However, two organisms were identified with high sequence identity to *Pseudomonas zhaodongensis* NEAU-ST5021 (98-100% sequence identity) and *Planococcus citreus* strain NBRC 15849 or *Planococcus rifietoensis* strain M8 (99% sequence identity). *Pseudomonas* sp. have diverse capabilities for degradation of organic substances including the

aromatic compounds of crude oil, formaldehyde, and alkanes. Marmulla and Harder (2014) showed that certain species of *Pseudomonas* can also catalyze the metabolic degradation of monoterpenes. *Pseudomonas* and other microorganisms that degrade terpenes can use these compounds as a carbon and energy source at low concentrations but, at high concentrations, need specialized adaptations in the cell membrane to prevent toxicity (Marmulla and Harder, 2014).

Table 2. Growth of Isolates on Turpenoid, Heptane, and Linseed oil

Isolate		1A1	1A2	1A3	4A1	1-1	1-4
Turpenoid	0.8%	++ (B)	+++ (B)	++ (B)	-	++ (B)	-
	1.0%	-	-	-	++ (B)	-	++ (B)
Isolate		2A1	5A1	5A2	1-2	1-5	
Heptane	0.8%	+ (B)	-	-	+ (B)	-	na
	1.0%	-	++ (B)	+ (-)	-	+ (B)	na
Isolate		3A1	6A1	6A2	1-3	1-6	
Linseed Oil	0.8%	++++ (T)	-	-	++++ (T)	-	na
	1%	-	++++ (T)	++++ (T)	-	++++ (T)	na

Growth rated from: - (no growth), or + to ++++

(T) growth on media-solvent interface; (B) growth at bottom of tube

na: not analyzed

No growth was observed in non-inoculated tubes.

Three isolates were incubated with either heptane or oleic acid (a fatty acid found in linseed oil) for determination of the bioremediation potential for these solvents. Biofilms were observed growing in all of the inoculated tubes during the incubation period (Fig. 3). The isolates tested were found to break down oleic acid and heptane, as determined by changes in the GC/MS peak areas (Table 3). Over time, additional peaks were observed for both oleic acid and heptane.

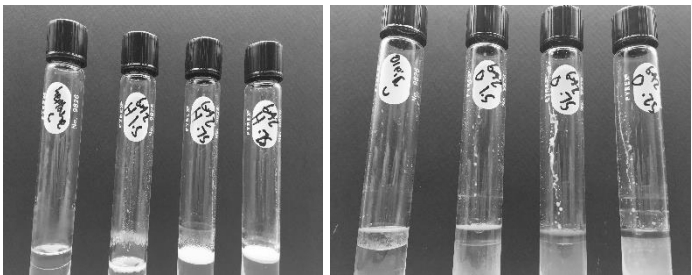


Figure 3. Growth of isolate 6A2 in three different concentrations (0.9%, 0.6%, and 0.3%) in heptane (left) and oleic acid (right). The first tube in each panel is a non-inoculated control.

Table 3. Retention times of new peaks identified after isolates were incubated for 14 d with either heptane or oleic acid							
	Control	6A1	6A2	1-6	J7	J19	TL8
Heptane							
Number of new peaks	0	2	5	2	1	3	10
Retention times for metabolite peaks (min)	N/A	0.76, 2.24	0.76, 1.64, 2.58, 2.72, 3.14	0.76, 2.24	2.24	0.92, 1.38, 2.24	0.92, 1.04, 1.18, 1.38, 1.60, 1.66, 1.82, 1.92, 2.12, 2.38
Oleic acid							
Number of new peaks	0	2	1	2	2	2	3
Retention times for metabolite peaks (min)	N/A	6.34, 6.06	6.34,	6.34, 6.44	6.34, 6.44	6.34, 6.44	6.06, 6.34, 6.44

N/A: not observed.

DISCUSSION AND CONCLUSION

In this study, we observed that certain microorganisms survive the extreme growth conditions found in art waste containers. In addition, we were able to isolate several microorganisms with different colony and cell morphologies (Table 1), indicating that a robust microbial community can be found in the art waste containers. These microorganisms could be of commercial or industrial interest because of their ability to live in a high solvent environment that also contains a high concentration of metal ions.

Among the microorganisms isolated from the art waste containers were *Pseudomonas zhaodongensis* and *Pseudomonas citreus*. *Pseudomonas zhaodongensis* was originally found in a saline soil environment in Zhaodong City, Heilongjiang Province, China (Zhang et al., 2015). *Pseudomonas citreus* and the related *Pseudomonas rifietoensis* are moderate halophiles (Galinski, 1993; Jiang et al., 2013; Meng et al., 2014). The saline tolerance of these bacteria could help explain how these microorganisms survive in the low-aqueous environment of the waste container, but does not indicate that they are also solvent resistant. Experiments to test the ability of these isolates to survive or grow in high concentrations of the solvents would provide interesting insight into their physiological properties. Further, some of the isolates that were not identified appeared to prefer growth at the bottom of the incubation tubes, indicating a preference for lower oxygen concentrations. These isolates might be especially useful in the remediation of art wastes inside of the waste collection containers.

We were able to determine that, when incubated with heptane or oleic acid, some of the isolates could decrease the concentration of the solvent with production of new metabolites. However, these results are preliminary and further analysis to confirm the identity of the metabolites produced during incubation is needed to better characterize the biodegradative potential of these bacterial isolates.

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Double-crested Cormorants Respond to Fish Stocking of Rainbow Trout in Suburban Ponds in Northern Utah

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Abstract

The Double-crested Cormorant (Phalacrocorax auritus), is a piscivorous bird that populates a wide variety of aquatic habitats, including fish-stocked ponds, behavior that has become increasingly important to wildlife managers in North America. We studied Cormorant locations and foraging activities compared with the fish-stocking dates in small suburban ponds of northern Utah. Based on prior research, we hypothesized that the number of cormorants at each pond would increase after stocking. Every morning during May 2017, we censused cormorants for 30 minutes at nine ponds. We also measured turbidity and water temperature. In general, Cormorant numbers increased after Division of Wildlife officers stocked ponds with Rainbow Trout (Oncorhynchus mykiss). In one case, a relatively high number (~1250) of trout were stocked in a pond that subsequently had the highest abundance of Cormorants (28). In contrast, stocking of Channel Catfish (Ictalurus punctatus) was asso-

ciated with small increases in Cormorants. Also consistent with our hypothesis, we observed the fewest Cormorants at the pond without fish stocking in May (although this was also the most turbid pond). Overall, stocking fewer Trout at a time could reduce attracting cormorants.

Introduction

Double-crested Cormorants (*Phalacrocorax auritus*) are highly adaptable piscivorous birds that inhabit many aquatic habitats in North America. They are powerful swimmers that dive to catch their prey (Grémillet et al., 2006). Although once endangered (Double-crested Cormorants remain protected under the Migratory Bird Act), the species has recovered. This has caused foraging on sport and commercial fish populations to become an increasing a logistical and economical concern (Dorr & Fielder, 2017).

The Utah Division of Wildlife Resources (UDWR) manages sport-fishing opportunities for the public in suburban ponds along the northern Wasatch Front. Double-crested Cormorants can prey heavily on the Rainbow Trout (*Oncorhynchus mykiss*) stocked in these ponds (Sowards et al., 2017). Although non-lethal harassment, which includes throwing rocks or using slingshots, lasers, and pyrotechnics, can distract Cormorant foraging (Hawkes et al., 2013), these strategies require expensive manpower, disturb local communities, and potentially harass protected species. The purpose of this study was to improve planning in an effort to reduce Cormorant effects on these suburban fisheries without the need for harassment techniques.

To achieve this purpose, we studied the abundance of cormorants in relation to fish-stocking dates in nine small suburban ponds of Northern Utah. In a preceding study, Sowards et al. (2017) found preliminary evidence that Cormorant numbers increased in response to trout stocking. Thus, we further investigated this hypothesis by expanding the number of ponds observed.

Materials and Methods

Site Description

We conducted the study at nine ponds in northern Utah, located in Weber and Davis counties including Farmington Pond (40.9930 °N, -111.8890 °W), Jensen Nature Park Pond (41.0662 °N, -112.0537 °W), four Kaysville Ponds (41.0204 °N, -111.9415 °W), Maybey Pond (41.1088 °N, -112.0176 °W), Meadow Creek Pond (41.1704

°N, -112.0821 °W), and Steed Pond (41.1226 °N, -112.0438 °W). During the study, the UDWR routinely stocked these ponds for local anglers with Rainbow Trout and Channel Catfish (*Ictalurus punctatus*). The location and size of the ponds can be viewed at <https://wildlife.utah.gov/hotspots/>, along with additional information.

Field Sampling

We split the research assistants into two teams: one team surveyed Farmington and the four Kaysville Ponds, and the other team surveyed Jensen Nature Park, Maybey, Meadow Creek, and Steed ponds. We visited each pond daily, throughout May 2017, on a rotating schedule. This entailed starting with a different pond each day at 7:00 AM and proceeding through the ponds in the same order as the day before. In this way, each pond was sampled roughly the same amount of times at each time of day. We counted the number of cormorants at the beginning and end of a 30-minute period. For two ponds (Farmington, Meadow Creek), we also had comparable data from censuses completed in 2016. At each pond, we measured turbidity using a turbidity tube (Lawrence Enterprises Transparency/Turbidity Tube 111360, *cm*). We also measured wind speed and air temperature using a digital gauge (Benetech Anemometer GM816, *m/s* and °C). Finally, we also measured water temperature using a standard analog thermometer. These environmental factors were measured at the beginning of each 30-minute period.

Analysis

We determined the mean measures for water temperature (°C) and turbidity (*cm*), with a 95% confidence interval. We used the confidence interval to identify ponds that were outside the norm. We also determined the mean number of cormorants observed by pond, with a 95% confidence interval, for comparison. We plotted the daily number of cormorants along with the days of fish-stocking events to document pond-specific patterns. We included the two ponds studied in 2016 by Sowards et al. (2017)—Farmington and Meadow Creek—to show whether the trends observed in 2017 were comparable. Using just data from May 2017, we plotted the number of cormorants versus days post stocking to clarify the relation between these two variables. Any day on which stocking occurred was day 1, with subsequent days following. We analyzed the strength of this relation with a simple linear regression to determine how well-stocked Rainbow Trout numbers predict cormorant numbers.

Results & Discussion

Water temperatures were similar at all ponds except Farmington Pond, which had a much lower mean temperature (Fig. 1). Water clarity was highest (>40 cm) for Farmington, Kaysville South, Kaysville Middle-south, Meadow Creek, Jensen, and Steed ponds; while Maybey Pond had the lowest clarity (<20 cm) (Fig. 2). Mean Cormorant number was exceptionally high at Jensen Pond (e.g., 28 cormorants on May 7, 2017). This pond had ‘normal’ water temperatures (defined as temperatures of 14–20°C) and high water clarity (~50 cm). The mean number of cormorants was exceptionally low (maximum daily census = 2 on two dates) at Maybey Pond, which had ‘normal’ water temperature and lowest water clarity (~15 cm) (Figs. 1 & 2).

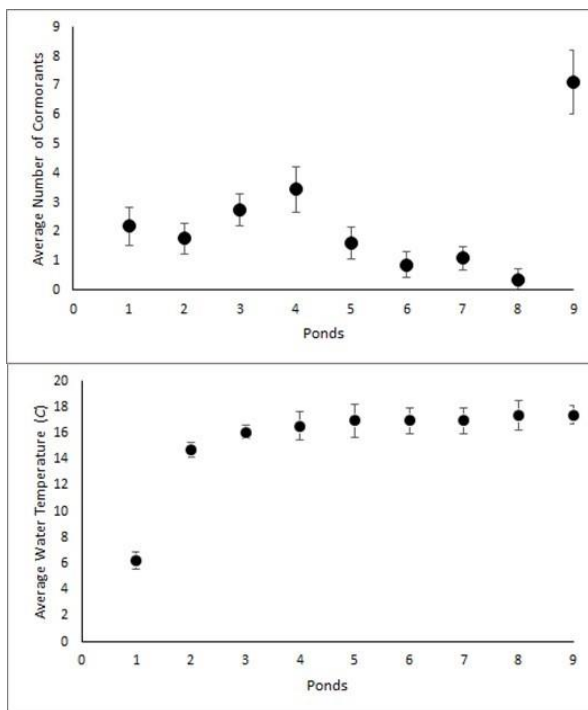


Figure 1. Graphs show the average water temperature for each pond (°C) (top) and the average number of cormorants (bottom). Error bars represent a 95% confidence interval. Pond numbers: 1-Farmington, 2-Meadow Creek, 3-Kaysville North, 4-Steed, 5-Kaysville Middle-South, 6-Kaysville South, 7-Kaysville Middle-North, 8-Maybey, 9-Jensen.

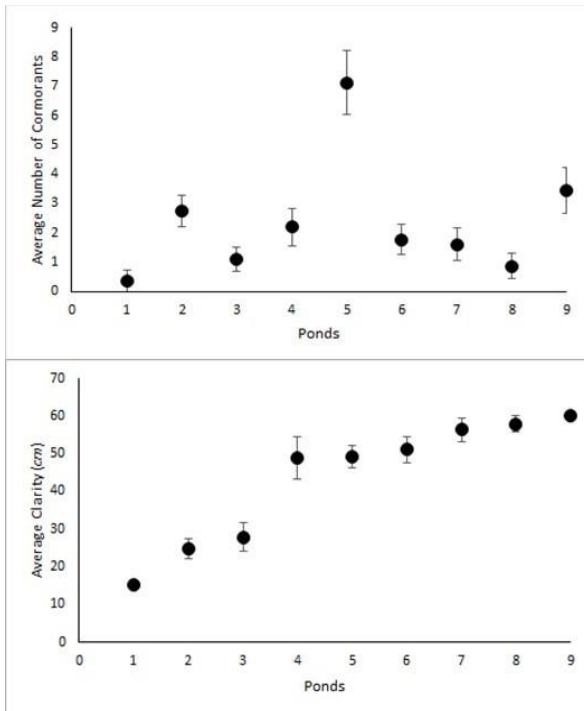


Figure 2. Graphs show the average clarity of each pond (cm) (top) and average number of cormorants (bottom). Error bars represent a 95% confidence interval. Pond numbers: 1-Maybey, 2-Kaysville North, 3-Kaysville Middle-North, 4-Farmington, 5-Jensen, 6-Meadow Creek, 7-Kaysville Middle-South, 8-Kaysville South, 9-Steed.

As observed by Sowards et al. (2017), Cormorant numbers generally increased after Rainbow Trout stocking at Farmington and Meadow Creek ponds (Figs. 3 & 4). This supports their finding of a positive relation between day of stocking and Cormorant abundance. Further, at the Kaysville ponds, cormorants were most numerous in the north pond, where stocking occurred, and numbers increased modestly after stocking (Fig. 5). The number of cormorants decreased incrementally in ponds further south. Most notably, relatively high Rainbow Trout stocking in Jensen Pond corresponded with relatively high Cormorant numbers. Finally, a lack of stocking during May corresponded with the lowest Cormorant numbers in Maybey Pond (Fig. 6), and stocking Steed Pond at an average rate produced a trend similar to that observed at Farmington and Meadow Creek ponds (Fig. 6).

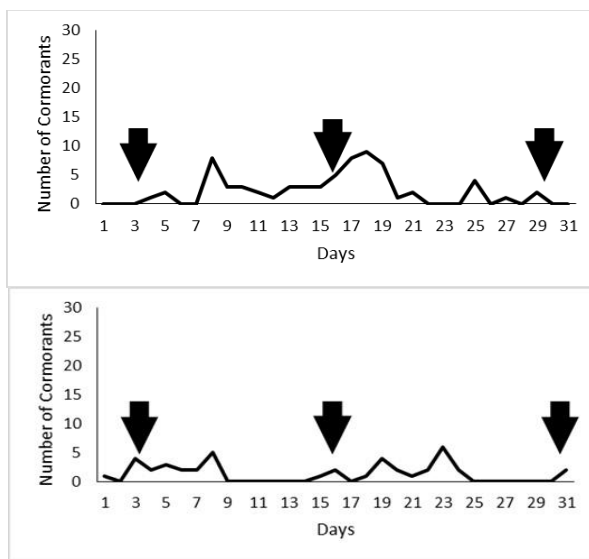


Figure 3. Number of cormorants present during daily census at Farmington Pond in May 2016 (top) and May 2017 (bottom). Black arrows represent the stocking dates of ~500 Rainbow Trout.

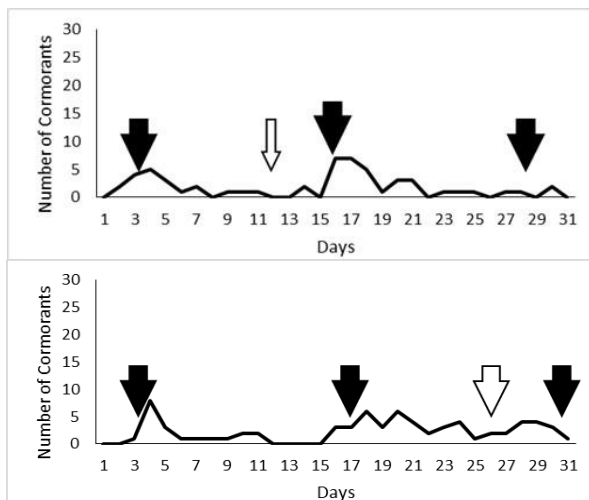


Figure 4. Number of cormorants present during daily census at Meadow Creek Pond in May 2016 (top) and May 2017 (bottom). Black arrows represent the stocking dates of ~500 Rainbow Trout. White arrow represents stocking dates of ~350 (narrow) and ~500 (wide) Channel Catfish.

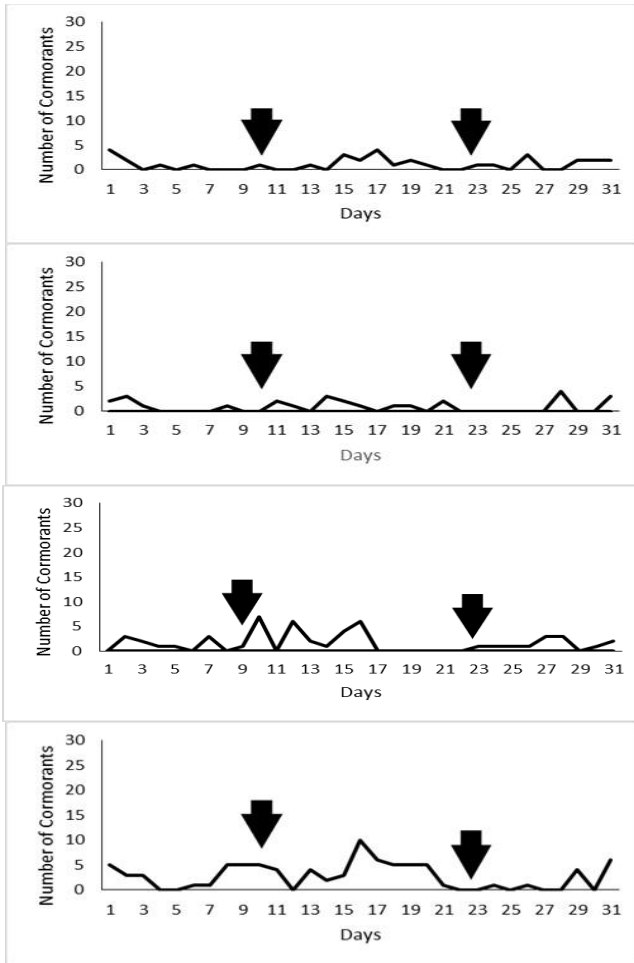


Figure 5. Number of Double-crested Cormorants present daily at the four Kaysville ponds, May 2017. All ponds are adjacent and interconnected by culverts. Trout stocking occurred in the north pond (top). Other ponds are middle-north (second from top), middle-south (second from bottom), and south (bottom). Black arrows represent the shared stocking dates of Rainbow Trout (~625 per stocking) into this complex.

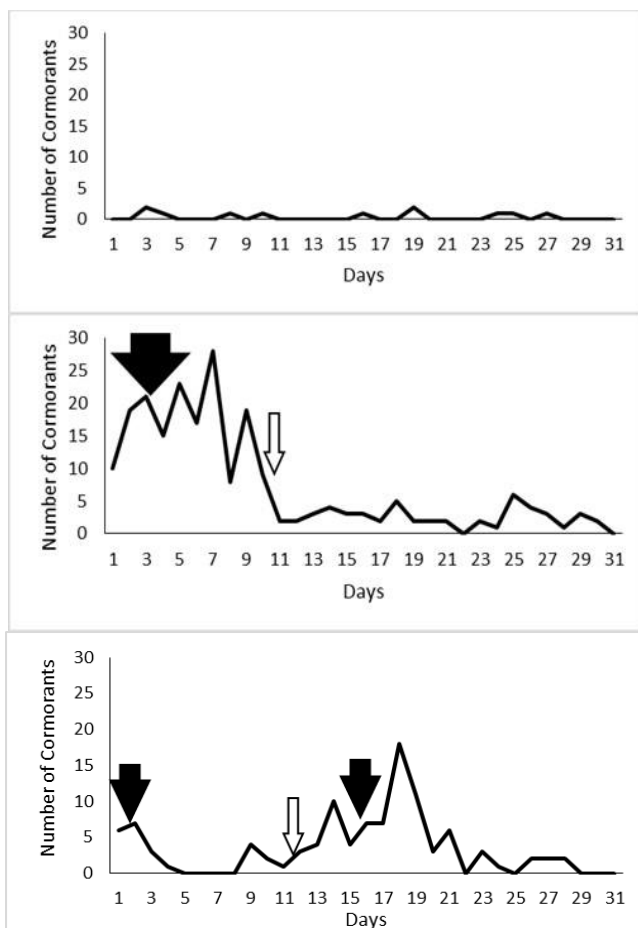


Figure 6. Number of Double-crested Cormorant present daily throughout May 2017. Top: Jensen Pond; Middle: Maybey Pond; Bottom: Steed Pond. Black arrows represent the shared stocking dates of Rainbow Trout, ~1250 (wide) or ~500 (narrow) per stocking. White arrow represents stocking dates of Channel Catfish, ~350 (narrow) and ~500 (wide). There was no scheduled stocking in Maybey Pond during May by the DWR. This was not intended to be a control pond.

Overall, the number of days after stocking only weakly predicted the number of cormorants present on any given day; days with Cormorant numbers >4 were all within 18 days of Rainbow Trout stocking, except at Jensen Pond (Fig. 7). The larger number of Rainbow Trout

stocked at Jensen Pond was associated with higher peak counts of cormorants (up to 28) and sustained visitation of higher numbers of cormorants for many more days after stocking (Fig. 7). The low number of Double-crested Cormorants observed at Maybey Pond was more likely due to a lack of Rainbow Trout prey than to higher turbidity, as Double-crested Cormorants can forage efficiently at low light (Enstipp et al., 2007) and related birds are efficient predators in turbid water because of effective underwater hearing (Grémillet et al., 2012; Hansen et al., 2017). Thus, overall observations are consistent with the findings of Sowards et al. (2017) that cormorants respond to availability of stocked Rainbow Trout in the study ponds. However, more research is needed to confirm these findings.

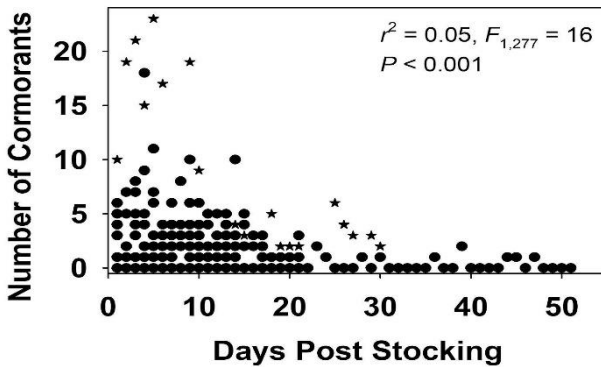


Figure 7. Daily observations of Double-crested Cormorant at select ponds at all nine study ponds in May 2017 versus the number of days since stocking of Rainbow Trout. Stars denote observations made at Jensen Pond, which was stocked with an exceptionally high number of Rainbow Trout (Fig. 6). Statistical results are from a simple linear regression.

Sowards et al. (2017) also documented high predation of cormorants on Rainbow Trout in Farmington and Meadow Creek ponds. Given this, concern for impacts of cormorants on fishing opportunities in the study ponds seems justified. The small size of all the study ponds and the reliance on stocked trout may make these suburban fisheries particularly susceptible to Cormorant predation. Double-crested Cormorants are generalist, opportunistic fish predators that respond to the abundance of prey, moving to new forage locations when prey abundance becomes low (Eisenhower & Parrish, 2009; Bugajski et al., 2013; Ridgway & Middel, 2015). Elsewhere in Utah, stocked Rainbow Trout are a preferred source of prey for cormorants (Modde et al., 1996). The related Great Cormorant also tracks prey abundance closely (Gagliardi et al., 2015) and is

attracted to locations of fish stocking (Kumada et al., 2013). In this latter species, prey availability closely relates to the ability of cormorants to meet their minimum energy requirements (Grémillet & Wilson, 1999), which is probably also true for Double-crested Cormorants (Enstipp et al., 2007). This suggests high densities of Rainbow Trout associated with stocking are the primary attractant for cormorants in the study ponds.

Some evidence suggests that Double-crested Cormorants (VanDeValk et al., 2002) and Great Cormorants (Gagliardi et al., 2015) tend to eat relatively small to moderate-sized fish; in this case, stocking larger fish might also reduce attraction for cormorants. Stocking larger Rainbow Trout could also increase angler satisfaction, as larger individuals may be more susceptible to angling, making them a good investment (Losee & Phillips, 2017, McCormick & Porter, 2014). Further, reducing Rainbow Trout stocking density does not necessarily reduce catch rates by anglers (Hyman et al., 2016).

In this study, stocking of Channel Catfish was less strongly associated with increased Cormorant numbers than for Rainbow Trout (Figs. 4 & 6). This may provide an alternative opportunity for anglers with less attraction for cormorants. Elsewhere, Double-crested Cormorants can have strong impacts on Channel Catfish aquaculture (Dorr & Fielder, 2017). However, some evidence shows that cormorants avoid larger individuals and prefer non-catfish species (Dorr et al., 2012). Lower preference for Channel Catfish could potentially reduce Cormorant number in the study area if these were the primary stocked species or if stocked Channel Catfish supplemented lower numbers of stocked Rainbow Trout. Stocking larger Channel Catfish could also be advantageous.

Overall, there seem to be several management options for further exploration. Our observations best support the recommendation to stock lower numbers of larger Rainbow Trout at a time, which could reduce attraction of cormorants. Additionally, Channel Catfish (or a catfish-trout combination) could be used as an alternative to Rainbow Trout. Future research is needed to test the success of these proposed management changes.

Acknowledgments

We thank Tyler Anderson, Kirt Longfellow, Kaden Cottle, Carter Murray, Daniel Akuoko, Jerome Tayag, and Rebecca Klingler for helping us gather the raw data. We also thank Duane Sowards, Bradley Hunter, and Chris Sessions for help in previous studies. Chris Penne from the Utah Division of Wildlife Resources, Erin Kendall from the WSU Office of Undergraduate Research, and Christopher Hoagstrom

from the WSU Department of Zoology (Project Mentor) provided support and aid. Roy and Clearfield city employees provided information about the study ponds.

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How Early Profitability Index Can Predict Bank Failure: Evidence from U.S. Bank Failure during 2008–2010

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Abstract

First, this paper examined the bank profitability index, return on asset (ROA), of the U.S. banks from quarter 1 through quarter 8 during 2008–2010 in determining the early bank failure prediction and found that the mean ROA successively decreased over quarters, in particular, during the immediate quarters ahead of the bank failure. Second, by applying the Probit model, the paper found the coefficient of the fifth quarter was significant, suggesting that bank failures can be warned or predicted as early as 15 months ahead of bank failure. The estimated model correctly predicts 98.74% of the U.S. banks that failed and 93.56% of the U.S. banks that survived. Overall, the estimated model correctly predicts 97.3% of the total banks (98.74% of the Dep=0 and 93.56% of the Dep=1 observations). The paper provides policy prescriptions that bank regulators and examiners should seriously scrutinize the ROA as early as the fifth quarter(s) and warn bank management when the ROA becomes significantly negative for two consecutive quarters.

1. Introduction

During the U.S. easy monetary policy of 2002–2007, banks supplied loans easily. They offered subprime mortgage rates, which were significantly lower than the prime rate, and did not maintain the strict procedure of fulfilling credit requirements, minimum collateral in particular. As a result, buying houses was easy, which generated a bubble in the U.S. housing market. When housing prices plummeted, the value of collateral against loans became insignificant. Defaults of mortgage payments increased. Consequently, banks' returns on asset (ROAs) and non-performance loans (NPLs) as a percentage of total loans increased leading banks' liabilities exceeding their assets. When banks' liabilities exceeded the assets following NPL, banks became insolvent as well as illiquid, leading to large bank failures. Such large bank failures had not happened since the Great Depression of the 1930s.

The study of bank failure and early prediction is important for several reasons. First, bank regulatory authorities are very interested in developing early warning systems to help predict impending bank failures. By doing so, regulatory authorities may reduce the cost of failures and even prevent failure. Second, bank failures have huge economic costs. Preventing a bank failure can save billions of taxpayer dollars. Third, a sound and stable banking system is important for economic growth. Public confidence in the banking system is shaken or deteriorated when there are large bank failures. Preventing bank failure through early warnings/predictions helps restore public confidence in the banking system. Thus, preventing a bank failure through early warning devices provides not only stability to the functioning of financial institutions but also protects the economy from entering into a recession.

There are several indicating factors that bank management/regulators can seriously examine before a bank is declared a failure. The quarterly ROA is one of them. Bank management should regularly scrutinize the average movement of the ROA of a bank compared with the ROA of the pair-group. This paper shows that the ROA provided an important signal when the average ROA of a bank significantly declined compared with that of its pair-group.

The survey of literature shows no evidence of the studies using the ROA, exclusively the ROA of lagged quarters as a predictor. So, this study is an important contribution to the literature of the early bank failure prediction.

A short survey of bank failure literature is discussed in Section 2. Data and methodology are outlined in Section 3. Section 4 provides empirical results and conclusions.

2. Survey of Literature

The study of bank failure prediction and bankruptcy has been a very popular topic for researchers since the 1930s when Secrist (1938) published his pioneering study that focused on national banks that failed and the banks that survived during 1920s.

Beaver (1966) was one of the first researchers to study bankruptcy prediction. In predicting bankruptcy he used several financial ratios and the predictive ability of those financial ratios.

Altman (1968) introduced bankruptcy models based on discriminant analysis and classified bankruptcies according to five financial variables: (i) working capital/total assets; (ii) retained earnings/total assets; (iii) earnings before interest and taxes/total assets; (iv) market value of equity/total debt; and (v) sales/total assets. He found these to be important in predicting bankruptcy.

Barr and Siems (1996) claimed to have built the first two new models for bank failure prediction. In one model, they used CAMEL rating system variables (Capital adequacy, Asset management, Management ability, Earning, and Liquidity risk) in which they used a new measure of efficiency representing management quality (M). In both the one-year-ahead model and the two-year-ahead model, they found, among the CAMEL variables, the new efficiency measure, M, obtained from Data Envelopment Analysis (DEA) developed by Charnes et al. (1978), to be a significant factor in predicting bank failure.

Kolari et al. (2002), applied the logit approach on a small sample of banks for predicting the large U.S. commercial bank failures and found bank failures could be predicted as early as one to two years prior to the failure.

Jordan et al. (2010) studied banks' failure risk using multiple discriminant analysis and found that bank failure could be detected up to four years prior to failure for banks that failed between February 2, 2007, and April 23, 2010.

Zaghdoudi (2013) examined Tunisian bank failure applying logistic regression and found that a bank's ability to repay its debt, its operational variable, bank profitability per employee, and the leverage ratio had a negative impact on the probability of failure.

Using a large quarterly data set of Federal Deposit Insurance Corporation (FDIC)-insured U.S. banks from 1992 to 2012, Mayes and Stremmel (2012) contrasted two methods, the logit technique and the discrete survival time analysis, to predict bank failures and drew inferences about the stability of contributing bank characteristics. The models incorporated CAMELS indicators and macroeconomic variables and

contrasted risk-based and non-risked-weighted measures of capital adequacy. They found that the non-risk-weighted capital measure and the adjusted leverage ratio could best explain the bank distress and failures.

Li and Wang (2014) developed a new Financial Early Warning (FEW) logit model using non-financial efficiency indicators of data envelopment analysis. The model was applied to a Chinese firm. They claimed that the proposed new FEW logit model had improved the accuracy of prediction and stability; the approach that used non-financial efficiency indicators to verify the results of the FEW logit model had significantly ensured the reliability of the FEW models.

The early study of Martin (1977) used both logit and DEA statistical methods to predict bank failures during 1975–1976 and found that the two models had similar results in terms of identifying failures/non-failures of banks.

Using a non-parametric proportional-hazard model on the Venezuelan banking sector, Molina (2014) found that a bank's ability to generate more and sounder profits during the crisis was the most important factor. The banks with higher ROA and more investments in government bonds were less likely to fail.

Arabi (2013) estimated bank failures in Sudan by logistic regression and discriminant analysis and found that earning was the most significant factor for bank failure followed by asset quality, liquidity, and capital adequacy.

Samad (2012) empirically examined the significant determinants of the credit risk variables of U.S. bank failures. Applying the Probit Model, he found that among the five credit risk variables, the credit loss provision to net charge off, loan loss allowance to non-current loans, and non-current loans to loans were significant for predicting bank failures. These factors predict 76.8% to 77.25% of total observation correctly. The model predicts 97 out of 121 failures, i.e., 80.17%, correctly. Net charge off to loans and loan loss to non-current loans, although usually reliable measures, were not significant predictors for the U.S. bank failures during 2009.

Samad (2011) examined failed and non-failed banks using ANOVA and Kruskal-Wallis K tests and found that failed banks had significantly lower capital ratio than those of non-failed banks.

Thomson (1991) studied the factors for the commercial bank failures during the 1980s. He found that the economic environment in which banks operated affected the probability of bank failure. The model for the bank failure was estimated during 1984–1989.

The survey of literature shows no evidence of the study of early bank failure prediction using the ROA, exclusively with lagged ROA as

the predictor. Therefore, this study is an important contribution to the literature of the early bank failure prediction.

3. Data and Methodology

Data

This study examined 202 failed banks and 554 surviving banks in the U.S. during 2008–2010, i.e., total 756 banks. The quarterly ROA of each failed bank from the immediate 1st quarter through 8th quarter before the bank was declared a failure was collected from the FDIC. The quarterly data (ROA) for the surviving banks were also obtained from the same source (FDIC).

Methodology

This study applied a probit model. As the bank failure is a binary index (failure=1, non-failure=0), probit or logit is the appropriate model. Logit uses non-normal distribution to the probability of an event occurring, whereas the Probit assumes standardized normal distribution. The Probit Model is:

$$Pr(Y_i=1|X_i, \beta) = 1 - \Phi(-X'_i - \beta) = \Phi(X'_i \beta) \quad (1)$$

where Φ is the cumulative density function of the standard normal distribution which takes a real value ranging between zero and one.

The probability functions used in the Probit Model are the standard normal distribution. Being distribution functions, they are symmetric around 0 and variance equal 1, and they are bounded between 0 and 1 (Amemiya, 1981).

Using the conventions of notation, the estimated model can be written in general form:

$$Pr(Y_i=1) = F(x_{i1}, x_{i2}, \dots, x_{iM}, \beta_1, \beta_2, \dots) \quad (2)$$

where Y_i is a dependable variable that represents the final outcome: $Y_i = 1$ for failed banks, $Y_i = 0$ for successful banks. X_i are the number of explanatory variables that have impact on bank failures or successes; X_{ij} the value of i th variable for the j th observation. $\beta_1, \beta_2, \dots$ coefficient associated with explanatory variable X_i is estimated from the sample. In compact notation, equation (2) can be stated as:

$$Pr(Y_i=1) = (X_{it}\beta + U_t) \quad (3)$$

where $Y = 1, Y = 2, Y = 3$ are dependent variable representing failure or success ($Y_i = 1$ for failed banks, $Y_i = 0$ for successful banks) X_{it} is a $(1 \times k)$

vector of explanatory variables used and β is a $(k \times 1)$ vector of unknown parameters to be estimated. U_i is the white noise. Then the observed dependent variable Y_i^* is determined by whether y exceeds a threshold value, 0.5, in this paper. That is,

$$Y_i = \begin{cases} 1 & \text{if } Y^* \geq 0.5 \\ 0 & \text{if } Y^* < 0.5 \end{cases}$$

Robustness, i.e., expectation–prediction, of the model as well as the likelihood ratio (LR) statistics will be examined. The LR statistics test the joint null-hypothesis that all slope coefficients are simultaneously equal to zero and is computed as $-2(l(\beta)/l(\beta))$.

Marginal effects of probit variables are estimated. In probit or logit models, as Y is the density function of $\alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3$, i.e., $Y = F(\alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3)$, the marginal effect of X_i is calculated as:

$$\frac{dy}{dX_i} = F(\alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \dots \alpha_n X_n) * \alpha_i.$$

The model's goodness of fit is estimated from the Hosmer-Lemeshow and Andrews tests.

Dependent variable:

Y_i is binary variable: $Y = 1$ for failed banks; $Y = 0$ for surviving banks

Independent variables:

The independent variables were ROA of eight quarters, starting from the ROA of quarter 1 through 8 before the bank was declared failed.

ROA1 = 1st quarter ROA before the failure, ROA2= 2nd quarter ROA before the failure

ROA3 = 3rd quarter ROA before the failure, ROA 4= 4th quarter ROA before the failure

ROA5 = 5th quarter ROA before the failure, ROA6= 6th quarter ROA before the failure

ROA7 = 7th quarter ROA before the failure, ROA8= 8th quarter ROA before the failure

These variables were regressed on failure, $Y_i=1$. The relationship between independent variables, i.e., ROA, and dependent variable, Y , i.e., bank failure, can be expressed as:

$$\frac{\partial Y_i}{\partial ROA1} < 0, \frac{\partial Y_i}{\partial ROA2} < 0, \frac{\partial Y_i}{\partial ROA3} < 0, \frac{\partial Y_i}{\partial ROA4} < 0, \frac{\partial Y_i}{\partial ROA5} < 0, \frac{\partial Y_i}{\partial ROA6} < 0, \\ \frac{\partial Y_i}{\partial ROA7} < 0, \text{ and } \frac{\partial Y_i}{\partial ROA8} < 0.$$

where $Y_i = \begin{cases} 1 & \text{if } Y_* \geq 0.5 \\ 0 & \text{if } Y_* < 0.5 \end{cases}$

That is, the bank failure and the ROA are negatively related. The lower ROA is associated with the higher probability of failure.

The descriptive statistics of the independent variables, ROA, from lagged 8th quarter to lagged 1st quarter before the failure is presented in Table 1.

Variable	Obs	Mean	Std. Dev.	Min	Max
roa1	756	-1.576089	5.397832	-44.12292	8.69888
roa2	756	-1.134928	5.503061	-53.07961	9.244896
roa3	756	-.3662009	3.538594	-32.19188	9.979068
roa4	756	.0788661	2.836937	-27.00641	8.432458
roa5	756	.3257592	2.595324	-33.86286	8.298446
roa6	756	.767574	1.478726	-12.8312	8.009069
roa7	756	.8877342	1.370011	-11.3497	8.351371
roa8	756	.9786071	1.128878	-6.483645	9.636922

Table 1 demonstrates that the ROA declined successively. Most importantly, the average decline of ROA was more negative during the immediate quarter before a bank was declared a failure. The ROA of the 8th quarter, 7th quarter, 6th quarter, 5th quarter, 4th quarter, 3rd quarter, and 2nd quarter before the bank was declared a failure was 97.8%, 88.7%, 76.7%, 32.5%, 7.8%, (-36.6)%, (-113)%, and (-157.6)%, respectively.

4. Empirical Results

The result of the probit estimate for the bank failure is presented in Table 2.

Table 2 shows that the coefficients of the ROAs of 5th quarter, 4th quarter, 2nd quarter, and 1st quarter are not only negative but also significant. As the ROAs of these quarters were significant, the probit model of this paper suggests that bank failures can be predicted as early as the 5th quarter, i.e., a year and three months before the bank was officially declared a failure. The 5th quarter ROA was significant and the significance was 1% level.

Table 2. Probit regression result

probit Y roa1 roa2 roa3 roa4 roa5 roa6 roa7 roa8						
Probit regression				Number of obs	=	756
				LR chi2(8)	=	757.95
				Prob > chi2	=	0.0000
Log likelihood = -59.84408				Pseudo R2	=	0.8636

Y	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	

roa1	-.2581531	.0535687	-4.82	0.000	-.3631458	-.1531605
roa2	-.4801212	.1074932	-4.47	0.000	-.6908039	-.2694384
roa3	-.093257	.0857275	-1.09	0.277	-.2612799	.0747659
roa4	-.3735921	.1321575	-2.83	0.005	-.632616	-.1145682
roa5	-.4796231	.1807481	-2.65	0.008	-.8338829	-.1253634
roa6	.8740078	.2423327	3.61	0.000	.3990444	1.348971
roa7	-.0850785	.186529	-0.46	0.648	-.4506686	.2805117
roa8	.1247239	.16026	0.78	0.436	-.1893799	.4388278
_cons	-1.805859	.1647297	-10.96	0.000	-2.128723	-1.482994

Note: 5 failures and 74 successes completely determined.

Pseudo $R^2 = 0.863$ provides the goodness of fit of logistic model. It should be interpreted carefully. There are several pseudo R^2 developed. They are on a similar scale, ranging from 0 to 1, with higher values indicating better model fit, but they cannot be interpreted as one would interpret an OLS R-squared, and different pseudo R-squareds can arrive at very different values.

The probability of 0.0000 associated LR statistics = 757.95 rejects the null hypothesis that coefficients of all variables are simultaneously equal to zero.

Marginal Impact of Variable on Bank Failure

To see the impact of these quarters (ROA) on bank failures, the average marginal effect of ROA is calculated and presented in Table 3.

The low probability of Z-statistics associated with the 5th, 4th, 2nd and 1st quarter ROA, in Table 3, showed that they were significant predictors of the U.S. bank failure.

Marginal effect on the 5th, 4th, 2nd, and 1st quarter ROA, shows, in Table 2, that for every 1% decrease of the ROA, the probability of bank failure increased by 2%, 1.5%, 2%, and 1% respectively and the effect on failure is statistically significant. Among quarters, the 5th quarter ROA was the most significant. This is demonstrated by the value of the Z-statistics= -2.64. During the 5th quarter, a 1% decrease of the ROA increased the probability of bank failure by 2%.

Table 3. Marginal effect of the independent variable ROA on bank failure (Y=1)

Average marginal effects			Number of obs = 756			
Model VCE : OIM						
Expression : Pr(Y), predict()						
dy/dx w.r.t. : roa1 roa2 roa3 roa4 roa5 roa6 roa7 roa8						

		Delta-method				
		dy/dx	Std. Err.	z	P> z	[95% Conf. Interval]

	roa1	-.0109512	.0025338	-4.32	0.000	-.0159173 -.0059851
	roa2	-.0203674	.0045899	-4.44	0.000	-.0293634 -.0113714
	roa3	-.0039561	.0036321	-1.09	0.276	-.0110749 .0031628
	roa4	-.0158483	.0057426	-2.76	0.006	-.0271037 -.0045929
	roa5	-.0203463	.0077149	-2.64	0.008	-.0354672 -.0052254
	roa6	.0370766	.0102039	3.63	0.000	.0170774 .0570759
	roa7	-.0036091	.0078925	-0.46	0.647	-.0190781 .0118598
	roa8	.005291	.0068165	0.78	0.438	-.0080692 .0186511

Bank regulators should pay serious attention as early as the 5th quarter i.e. a year and three months ahead, when the ROA starts declining and the declines are significantly negative. Bank management should be alerted for necessary action when the ROA becomes significantly negative for two successive quarters. This is an important policy prescription of this paper

The predictive power of the estimated model for correct prediction and wrong prediction is provided in Table 4.

Table 4. Predictive power of the model variables

Expectation-Prediction Evaluation for Binary Specification						
Success cutoff: C = 0.5						
	Estimated Equation			Constant Probability		
	Dep=0	Dep=1	Total	Dep=0	Dep=1	Total
P(Dep=1)≤C	547	13	560	554	202	756
P(Dep=1)>C	7	189	196	0	0	0
Total	554	202	756	554	202	756
Correct	547	189	736	554	0	554
% Correct	98.74	93.56	97.35	100.00	0.00	73.28
% Incorrect	1.26	6.44	2.65	0.00	100.00	26.72
Total Gain*	-1.26	93.56	24.07			
Percent Gain**	NA	93.56	90.10			

In the left-hand table, the classification of observations as having predicted probabilities $\hat{p}_i = 1 - F(-x_i'B)$ that are above or below the specified cutoff value 0.5. In the upper right-hand table, we classify observations using $\bar{p}$, the sample proportion of $y = 1$ observations. This probability, which is constant across individuals, is the value computed from estimating a model that includes only the intercept term, C.

“Correct” classifications are obtained when the predicted probability is less than or equal to the cutoff = 0.5 and the observed $y = 0$, or when the predicted probability is greater than the cutoff = 0.5 and the observed $y = 1$. Based on the cutoff value = 0.5, 547 of the Dep = 0 observations and 189 of the Dep = 1 observations are correctly classified by the estimated model.

The sensitivity result, the fraction of $y = 1$ observations that are correctly predicted, shows that the model correctly predicts 98.74% of the U.S. bank failures, while the specificity result, the fraction of $y = 0$ observations that are correctly predicted, shows that the model correctly predicts 93.76% of the U.S. banks that survived.

Overall, the estimated model correctly predicts 98.74% of the observations (98.74% of the Dep = 0 and 93.56% of the Dep = 1 observations).

The gain in the number of correct predictions obtained in moving from the right table to the left table provides a measure of the predictive ability of this model. The gain measures are reported in both absolute percentage increases (**Total Gain**) and as a percentage of the incorrect classifications in the constant probability model (**Percent Gain**). The gain measures show the restricted model predicts that all 554 individuals will have Dep = 0. This prediction is correct for the 554 $y = 0$ observations, but is incorrect for the 202 $y = 1$ observations.

The estimated model improves on the Dep = 1 predictions by 96.56 percentage points, but does poorly on the Dep = 0 predictions (-1.26 percentage points). Overall, the estimated equation is 24.07 percentage points better at predicting responses than the constant probability model. This change represents a 90.10% improvement over the 73.28% correct prediction of the default model.

The *p-value* for the HL test is large while the value for the Andrews test statistic is small, providing mixed evidence of problems. As the Andrews Statistics (344.65) associated with their Prob=0.0000, the Chi-Sq provides support that there are no significant differences between the fitted expected values and the observed values. The estimated model provides a good fit.

Table 5. Goodness of fit for estimated model

Goodness-of-Fit Evaluation for Binary Specification Andrews and Hosmer-Lemeshow Tests Grouping based upon predicted risk (randomize ties)								
	Quantile of Risk		Dep=0		Dep=1		Total Obs	H-L Value
	Low	High	Actual	Expect	Actual	Expect		
1	8.E-22	0.0012	75	74.9666	0	0.03341	75	0.03342
2	0.0012	0.0025	75	75.8598	1	0.14020	76	5.28286
3	0.0025	0.0044	75	74.7417	0	0.25830	75	0.25919
4	0.0044	0.0069	76	75.5752	0	0.42475	76	0.42714
5	0.0070	0.0109	76	75.3181	0	0.68188	76	0.68805
6	0.0111	0.0201	75	73.8576	0	1.14239	75	1.16006
7	0.0205	0.1061	72	73.3080	4	2.69204	76	0.65883
8	0.1064	0.9824	29	30.9516	46	44.0484	75	0.20952
9	0.9827	1.0000	1	0.17319	75	75.8268	76	3.95611
10	1.0000	1.0000	0	4.8E-09	76	76.0000	76	4.8E-09
Total			554	554.752	202	201.248	756	12.6752
H-L Statistic			12.6752		Prob. Chi-Sq(8)		0.1235	
Andrews Statistic			344.6599		Prob. Chi-Sq(10)		0.0000	

Conclusion

This paper examined the ROA of eight quarters of 756 U.S. banks. Of these, 202 were failed banks and 554 were nonfailed. The descriptive statistics of the failed banks' ROAs shows that the ROA successively declined. The ROA of the quarter immediately preceding failure was negative in 157.6% compared with the ROA of 97.8% of the eighth quarter before the failure.

Probit model on bank failure, $Y = 1$, and non-failure, $Y = 0$, was regressed on lagged quarter/s in determining quarter(s) that had significant impact on the U.S. bank failure. Probit results found that fifth-quarter ROA was negative and significant. The significance of the coefficient of the quarter suggests that bank failures can be predicted as early as the fifth quarter, i.e., a year and three months ahead of the failure.

The study of marginal impact found that for that every 1% decrease in the ROA, the probability of the U.S. bank failure increased by 2% in the fifth quarter before the bank was declared a failure.

The probit estimate of this paper correctly predicts 98.74% of the U.S. banks that failed and correctly predicts 93.56% of the U.S. banks that survived. Overall, the estimated model correctly predicts 97.3% of the total bank failures (98.74% of the Dep = 0 and 93.56% of the Dep = 1 observations).

The paper provides policy prescriptions. Bank regulators should pay serious attention as early as the fifth quarter, i.e., a year and three months ahead, when the ROA starts declining and the declines are significantly negative. Bank management should be alerted for necessary action when the ROA becomes significantly negative for two successive quarters.

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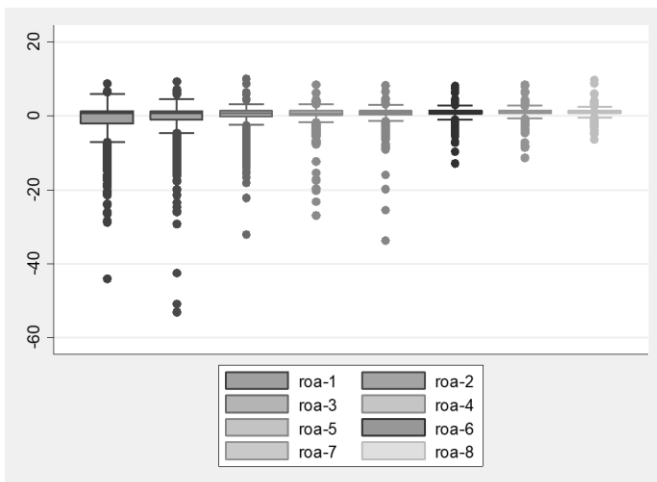
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Appendix. Box plot for data series



Note: As data show outliers, the paper applied the probit model excluding those outliers.

Educator Ethic Laws Across the United States

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Abstract

This study provides a singular compilation and examination of ethic laws from all 50 states and the District of Columbia. Many professions have a single governing body that grants licensure and prescribes professional standards for its members. In the United States, individual states confer license and determine parameters of ethical behavior for those who teach. The education profession has multiple ethical codes, which exist through numerous state laws. The purpose of the study was to survey state laws to determine the existence and substance of educator ethical codes. All states and the District of Columbia have at least one educator ethics law in statute, rule, or policy, or combination of source. Collected ethics laws were examined for similarities and differences in source, construction, and content. Through coding and structure analysis, three taxonomies were identified and labeled as the Troika, Teaching Standards, and Limited Models. A geographical clustering of similar

state laws was discovered. An accounting of existing state laws is provided with implications. The degree of variability and compatibility was noted and quantified in source, structure, content of state laws and geographical location.

Introduction

The need for ethical educators is proclaimed by educators, professional organizations, and governments worldwide. Educator ethics has been discussed as a concern in Australia (Forster, 2012), Brazil (Quayle, 2009), Canada (Campbell, 2000), England (Maxwell, 2017; Page, 2013), New Zealand (O'Neill & Bourke, 2010), Nigeria (Ojogwu, 2008), and Israel (Fisher, 2013). The term "ethics" commonly refers to a set of values, responsibility, duty, behaviors, and judgments. Dewey (1903) saw professional ethics as a moral responsibility to society. Ethics goes beyond adherence to legal codes to include a sense of rightness and wrongness (Frank et al., 2010), an understanding of foundation moral concepts (Craft, 2013), and individual factors (Wallach, 2010). Ethical educators are those who adhere to professional or legal standards (O'Neill & Bourke, 2010), whereas unethical educators either knowingly or unknowingly (Boon, 2011; Page, 2013) depart from prescribed and accepted codes of behavior. Previously, ethical behavior was understood to be the domain of licensing, but an erosion of public trust from misbehaving professionals created a demand to thrust professional ethics into legal oversight (Cavaliere et al., 2010). Educator misconduct is a serious threat to schools and the public. In the last decade, approximately 4.5 million students in the US reported educator misconduct of some type (Umpstead et al., 2013).

Professionals are generally considered to have specialized training, skills, knowledge, credentials, self-regulation, independent judgment, and a sense of duty to the general public (Buhai, 2012). This duty can be attributed to Greek origins that professionals provide service to the public. Professional training must impart necessary knowledge and skills, while also instilling a commitment to follow ethical standards (Bourke & O'Neill, 2009). A hallmark of professionalism is ethical conduct and competency for its members (Buhai, 2012; Leach & Harbin, 2010).

Before professional practice begins, a licensing entity confers the right to practice, signifying sufficiency in training and fitness in skills. Many professions have boards that set conduct standards, award licensure, and self-regulate members to ensure ethical ability. Self-regulation of behavior connotes professional internal control and public protection (Dresscher, 2008). Being awarded certification by a granting entity is not

enough to practice; the individual must also agree to follow prescribed methods of practice and behavior, including ethic or conduct codes.

Ethical Behavior

Professional ethical codes establish practices, recognize values, and respond to legal mandates (Saunders, 2010). Although the education profession sets standards, it does not grant licensure nor enforce standards. Instead, each state has sovereign power to grant educator licensing and monitor ethical behavior. This power to award teaching licensure and prescribe ethical legal mandates has brought to the forefront discussions for the profession to self-regulate teacher behavior (Smith, 2014), better prepare future teachers (Burant et al., 2007; Warnick & Silverman, 2011), and delve deeper into the individual decision-making process (Wallach, 2010). While ethic laws may provide guidance for ethical behavior, they are not a panacea and instead may undermine professional standing if educators are viewed as unable to self-regulate (Kerns & Sampson, 2011) or fail to understand terminology or concepts in those laws (Maxwell, 2017).

An additional concern exists that a singular professional code will limit teaching to a narrow, acceptable range (Clark & Moore, 2013). Instead of enacting a singular code or legal requirement, many support requiring ethical training (Cameron & O’Leary, 2015; Strike & Soltis, 2009; Warnick & Silverman, 2011). In this view, deficiency in educator ethics is not due to scarcity of ethics laws but to the paucity of ethical training (Burant et al., 2007). The lack of understanding how educators make ethical decisions raises another concern (Bagdasarov et al., 2015; Wallach, 2010). The sheer number of unethical occurrences in tandem with a void in the ethical decision-making process unites to create a conducive climate that is prone to curb misconduct through legislation (Guaneri & Achilles, 2009) instead of ethical education. While law presence helps to reduce questionable, illegal, or unethical behaviors (McKinney et al., 2010) existence of laws alone is not enough to “influence ethical behavior or ethical awareness.” (Craft, 2013, p. 249). The combining complexities of laws, training, and behavior may not be suited for a singular approach to ethics (Strike & Soltis, 2009) nor to educator ethic training (Maxwell, 2017).

Ethics Laws

Educator ethics is further complicated by multiple sources of law in the United States. The source of law provides some indication as to its permanence (Hirsch et al., 2009). State statutory laws emanate from legislative bodies, require gubernatorial approval to become law, and thus

are generally more permanent than regulations. Regulations (or rules) are written by the administrative branch. Regulations may be dependent on statutory law for existence or permanence. Judicial or case law is produced when the judicial branch interprets or refines existing law. Policies are a less precise term (Sindelair et al., 2010; Zirkel, 2014) as their source and purpose are not so clearly defined. Policies can be written by school boards to supplement laws or supply law if one does not exist. Education board policies are likely the most transient and transparent law type. Educators may have more influence over policies than other law types (Yudof et al., 2002).

Examination of laws among some states has begun, but a compendium of state educator ethic laws with their source, construction, and content is not found. Some of the first collections of educator ethic laws were in dissertation work with limited scope and content (Banter, 2003; Blackburn, 1998; Rogers, 2002). Later, Guarneri and Achilles (2009) indicated 25 states had ethics laws but did not list the states. The laws of four states were compared and discussed in terms of ethical duties, consequences of unethical behavior, application of court rulings, and theoretical underpinnings, but source or construction was not given (Umpstead et al., 2013).

Zirkel (2014) provided a comprehensive treatment on ethic laws for school leaders. Laws from all states were harvested and evaluated to determine the existence of “governmentally sanctioned” codes for school leader ethics, the status of those codes, major and subset content categories, and sanctions for code violations. Thirty-four states were identified having an ethics law for school leaders.

Others used judicial proceedings as the legal lens to view educator ethical policy for teacher misbehavior or dismissal legality (Permuth & Egley, 2002; Umpstead et al., 2013). Two seminal U.S. Supreme Court cases, *Brown v Board of Education* and *Plyer v Doe*, explored an ethical framework in educational leadership decision-making (Bon, 2012). Recent work has focused on educator ethical training requirements in Australia and Canada (Boon, 2011; Forster, 2012; Maxwell et al., 2016) and understanding of ethical decision-making to improve self-regulation, but examination of legal content in the U.S. remains elusive.

Study Aims

Each state has the sovereign right to determine qualifications, behaviors, and ethical laws for its educators. Too little is known about state ethic laws to determine source, analyze content for similarities or variation, or construct a framework. The following questions were asked: Which states had laws regarding educator ethical conduct and what is the

source of those laws? What similarities or differences in content or structure can be found in state laws? Does a geographical pattern for state ethics laws exist?

Methodology

Ambiguity in existence, content, source, and construction of state ethic laws created the need to establish a quantifiable detailed accounting and create a foundation for additional investigation. Using a descriptive study design, state statutes, administrative regulations, and state board policies were collected. State law data were obtained through systematic online searches of official state government websites and LexisNexis over a nine-month period and then verified. Searches used truncated key words: teacher*, educat*, profession*, moral*, principle*, code*, ethic*, and standard*. Law source was determined by placement in statutes, regulations, or state school board policies. Data were recorded in a word document, resulting in 431 pages of text independently read and coded by three researchers for theme elements and commonalities and variances in content and structure. Computer software was not used in coding. Tally keeping quantified the number of state laws, the source of those laws, and similar or dissimilar themes. Initial content analysis discovered 31 major categories that included dispositions, actions, and duties. These categories were then indexed into 19 themes, which were further refined to create a classification system of three taxonomies. Themes were found to exist across taxonomies in differing arrays. Weight or importance was not assigned to the identified themes. Themes and models were reviewed by a fourth researcher to ensure trustworthiness. Lastly, cross-checking for 100% inter-rater agreement among all researchers to verify themes and model decisions with the original data set was performed to reduce influence of overlooked elements or details magnified by the coding process.

Results

All states and the District of Columbia have at least one source of educator ethic law. Nineteen states had statutory ethic laws, 34 states had regulatory rules, and 45 states had policies (Table 1). Laws from all three sources were found in 11 states. Statutes were generally the briefest and broadest laws. Statute content was often limited to authority for creation or enforcement of educator ethic laws (Delaware or Vermont), but could be very detailed and prescriptive (New Mexico or Iowa). Rules were usually more prescriptive than statutes. Some states had very detailed ethical rules in content, organization, and execution (Minnesota or Utah),

while other states were focused on educator competencies (Massachusetts or Arizona). Policies were the most common law type and usually more descriptive than statutes (New Jersey). Generally, policies were the most informative and detailed (Alabama or Kansas) while offering the greatest distinction between competency and ethics (Maine or Wisconsin).

Table 1. Sources of State Educator Ethical Laws

State	Statute	Rule	Policy
Alabama	X	X	X
Alaska	X		X
Arizona		X	X
Arkansas	X	X	X
California	X	X	X
Colorado	X	X	X
Connecticut		X	X
Dist. Columbia			X
Delaware		X	X
Florida		X	X
Georgia	X	X	X
Hawaii	X		X
Idaho		X	X
Illinois		X	X
Indiana	X		
Iowa		X	X
Kansas			X
Kentucky	X	X	X
Louisiana		X	X
Maine	X	X	X
Maryland			X
Massachusetts		X	X
Michigan		X	
Minnesota		X	X
Mississippi			X
Missouri			X
Montana			X
Nebraska		X	X
Nevada	X		X
New Hampshire	X	X	
New Jersey	X	X	X
New Mexico		X	X
New York			X
North Carolina		X	X
North Dakota		X	
Ohio			X

Oklahoma		X	X
Oregon		X	X
Pennsylvania	X		X
Rhode Island	X		X
South Carolina		X	X
South Dakota	X	X	X
Tennessee		X	
Texas		X	
Utah	X	X	X
Vermont	X		X
Virginia		X	X
Washington	X	X	X
West Virginia			X
Wisconsin		X	X
Wyoming			X
Total	19	34	45

Variance was found not only in source but also in application. Laws applied to educators in 27 states, teachers in 22 states, administrators or principals in 21 states, and other professionals (licensed or certified personnel, paraprofessionals, practitioners, or pupil service employees) in 17 states.

Investigation of law content construction allowed for deeper analysis. Content analysis discovered 31 categories initially sorted into 24 topics. These categories were then indexed into 19 major content themes further refined to create a classification system of three taxonomies later named Troika, Teaching Standards, and Limited Models (Table 2). The Troika Model is distinguished by three typical duties (student, profession, or state). Themes in the Teaching Standards Model closely align with teaching competencies. The Limited Model is restricted in either scope or content. North Carolina's administrative rule aligns with the Teaching Standards Model while its policy follows the Troika Model. Significance was not determined in identified themes among the three models.

Table 2. State Laws by Model Type			
State	Troika	Standards	Limited
Alabama		X	
Alaska		X	
Arizona		X	
Arkansas		X	
California		X	
Colorado		X	
Connecticut	X		

Dist. Columbia			X
Delaware	X		
Florida	X		
Georgia		X	
Hawaii	X		
Idaho		X	
Illinois	X		
Indiana			X
Iowa		X	
Kansas	X		
Kentucky	X		
Louisiana		X	
Maine		X	
Maryland			X
Massachusetts			X
Michigan		X	
Minnesota		X	
Mississippi		X	
Missouri			X
Montana	X		
Nebraska	X		
Nevada			X
New Hampshire		X	
New Jersey		X	
New Mexico	X		
New York		X	
North Carolina	X	X	
North Dakota	X		
Ohio		X	
Oklahoma	X		
Oregon	X		
Pennsylvania		X	
Rhode Island	X		
South Carolina			X
South Dakota	X		
Tennessee	X		
Texas	X		
Utah		X	
Vermont		X	
Virginia		X	
Washington		X	
West Virginia			X
Wisconsin			X
Wyoming			X
Total	18	24	10

Eighteen states followed the Troika Model (Table 3). The laws in this model were distinguished by ethical duty labeled as responsibility in four states, an obligation in five state laws, commitment in eight states, and conduct in one state. Ethical duty specifically pertained to students, the profession, self, the community, and the state or district. Most of these states (13) required ethical duty in three areas (student, profession, and state or district). Ethical duty was delineated in as few as two areas (Tennessee) to all five areas (Illinois).

Table 3. Troika Model State Laws

State	Legal Accountability to			Legal charge		Label
	Student	Profession	Community	Self	State	
CT	X	X	X			Resp
DE	X	X	X			Comm
FL	X	X	X			Obl
HI	X	X	X			Comm
IL	X	X	X	X	X	Resp
KS	X	X	X			Resp
KY	X	X	X			Obl
MT	X	X	X			Comm
NB	X	X	X			Comm
NM	X	X	X			Comm
NC	X	X			X	Comm
ND	X	X	X			Comm
OK	X	X	X			Comm
OR	X	X			X	Obl
RI	X	X		X	X	Resp
SD	X	X	X			Obl
TE	X	X				Obl
TX	X	X				Cond
Total	18	18	13	2	4	

Resp = responsibility; Obl = obligation; Comm = commitment; Cond = conduct.

The Teaching Standards Model (24 states) had the most varied and numerous themes (Table 4). The 16 content themes are professional disposition, professional practice, contractual obligations, legal compliance, teaching standards, relationships, students, controlled substances, testing, authority, funds, remuneration, technology, confidentiality, safety, and reporting. There were as few as four themes (New Hampshire) to as many as 13 (Iowa or North Carolina), with an average and mode of eight themes present in a state law. Themes most frequently

included were relationships (21 states), legal compliance (19 states), professional dispositions, professional practice, and confidentiality (16 states each), and students (13 states). Variation was found to exist in application as well as theme number. For example, Minnesota duplicated themes in separate laws for administrators and teachers, while Mississippi law was applicable to all educators.

Table 4. Teaching Standards Model State Laws

State	Professional disposition	Professional practice	Contractual obligations	Legal compliance	Teaching standards	Relationships	Students	Controlled substances	Testing	Authority	Funds	Remuneration	Technology	Confidentiality	Safety	Reporting
AL	X	X	X	X		X		X			X	X		X		
AK		X			X	X	X			X			X		X	X
AR	X	X		X	X	X	X		X				X			
AZ	X			X		X		X			X	X		X		X
CA	X	X		X		X	X									
CO	X			X		X	X									
GA	X	X	X	X		X		X			X	X	X	X		X
ID	X	X	X	X		X		X			X	X		X		X
IA		X	X	X	X	X	X	X		X	X			X	X	X
LA	X	X					X		X					X		
ME		X	X	X		X								X	X	
MI				X	X	X	X									
MN		X	X	X	X	X				X				X		X
MS	X	X	X	X		X		X			X	X		X		
NH		X		X		X										
NJ		X		X	X	X	X								X	
NY					X	X	X							X		
NC	X	X	X	X		X	X	X		X	X	X		X		X
OH	X			X		X								X		X
PA	X	X	X	X	X	X	X							X		
UT	X	X	X	X		X					X			X		X
VT				X		X	X	X			X	X		X		X
VA	X	X					X									X
WA		X			X	X		X				X				X
Total	16	16	10	19	10	21	13	9	3	3	9	9	2	16	4	11

the country followed the Troika Model. The Teaching Standards Model was more prominent in the eastern half of the United States, with a smaller grouping of western states. Not only did nearby states have similar model types but language in the laws was also similar or even duplicated exactly in many states. Limited Model states were the most geographically scattered.

Discussion

Educator ethic laws exist in all states and the District of Columbia. The laws found in statutes, rules, and policies can be identified as the Troika Model (a typical concentration of three duties to students, the profession, the community, self, or the state or district), the Teaching Standards Model (closely resembling professional standards or dispositions), and the Limited Model (narrow content or broad statement).

Previous work supplied important and early information on state educator ethic laws but was less comprehensive in disclosure of the type of law, the number of state laws analyzed (Bon, 2012; Umpstead et al., 2013), similarities in law content, structure, or geographical location (Banter, 2003; Zirkel, 2014). The study went beyond listing state laws to clarify the complexity among ethics laws and to provide the source and geographical mapping of those laws. Knowing the source of law gives some indication of its permanence and reach (Hirsch et al., 2009). Mapping the laws suggests neighboring states view educator ethics similarly. The clustering of similar model type and language in state laws may address teacher training to aid in certification reciprocity, reflect a construct of similar attitudes (Clarke & Moore, 2013), or be a byproduct of court rulings influencing contingent state laws (Bon, 2012; Umpstead et al., 2013). The added specificity in legal source and geographical location, as well as detail given in themes and models, provides a new approach to viewing educator ethics (Burant et al., 2007; Craft, 2013).

Variance and commonalities exist among the state laws in terms of source, structure, and content. The dissimilarities in laws reflect the differing and unique political context, values, and competing and complementary circumstances within each state (Hirsch et al., 2009), while similarities could accentuate a common understanding for the need of educator ethics (Campbell, 2000). It is important to note that similarities do not guarantee understanding of, obedience to, or agreement with those laws. Presence of law does not guarantee the absence of unethical behavior or the obedience to law (Craft, 2013). Additionally, existence of similar ethical laws does not mean uniform implementation of those laws, nor does variance in law presuppose decreased awareness or adherence among educators. Although professional skills are legally specified in

many states, they can be subjective and difficult to enforce in reality (Sindelar et al., 2010). Prescriptive laws can assist in fidelity implementation of the law (Hirsch et al., 2009) and safeguard adherence, but may limit flexibility to address future concerns. Succinct or broad wording mandating ethical behavior may also introduce confusion in expectations of educators.

Law presence reduces questionable behavior (McKinney et al., 2010) and may undermine professional ethics (Kerns & Sampson, 2003), yet underscores and speaks to the reality of critical demand for ethical educators in the United States (Burant et al., 2007). Variability in state laws evidences that a common ethical law does not exist. The data from this study suggest that without a common set of professional ethical standards for educators, policymakers will fill the void with individual state laws. While awareness of law may be a necessary step in halting the harms caused by unethical educators (McKinney et al., 2010), it is not the only way to way to improve ethical professionalism. Other strategies include ethical training (Strike & Soltis, 2009; Warnick & Silverman, 2011) and understanding of individual decision-making process (Bagdasarov et al., 2015; Wallach, 2010).

Limitations

Factors inherent in descriptive research and the scope of the study limited the research. The data obtained only describe existing state laws at a given time. While data gathered were vast and inclusive attention given, collection was limited solely to specific terms and purposes. Although substantial care was taken to make sure data were accurate at the time gathered and each state site was searched multiple times for correct and salient laws, states regularly change laws. The results do not provide information regarding educator understanding, compliance, sanctions, or punishments for failure to adhere to law.

Implications

The analyses provide comparison of state laws, present a reference point to gauge future changes, and offer implications for educator ethics dialogs. Variability in educator ethic laws will likely continue and may expand with or without a common conduct code. This diversity is not necessarily unwanted. Law variation may be required to accommodate inherent differences among the states and educator responsibilities. However, multiplicity in state laws is a double-edged sword. Legal broadness permits states and districts latitude in dealing with individual circumstances but also opens the door for unintended confusion to what is acceptable ethical behavior among educators.

Additional research can now gauge changes in subsequent state laws. A bifurcation of educator ethical exploration into laws and decision-making is warranted (Bagdasarov et al., 2015). Future research should determine if state laws are indeed producing ethical educators and increasing the likelihood of ethical decision-making. Based on variation found in this study, the education profession might be supported in the desire to create a singular ethical code to guide new and experienced educators (O'Neill & Bourke, 2010) or to explore the individual decision-making processes of educators to promote ethical behaviors and decrease unethical behaviors (Wallach, 2010).

Policymakers and researchers need a better understanding of ethical behavior as laws set only minimum standard thresholds. Policy can be an effective lever ensuring commitment in practice (Hardman, 2008) if laws are clearly articulated to assure compliance (Sindelar et al., 2010) or align with individual understanding of ethical behavior (Bagdasarov et al., 2015). Professional standards should be largely guided by those in the profession (Dresscher, 2009), but without a legal component or individual commitment they may be inadequate to address the gravity of unethical consequences. As policy influences practice, policymakers and professionals are well advised to work together in the creation and implementation of ethical standards for all educators.

Those who prepare future educators must be cognizant of the current ethical and legal terrain in education. Expectations for ethical behavior of teachers must be raised (Boon, 2011). An increased teacher awareness of ethical behaviors, combined with increased training (Clarke & Moore, 2013; Warnick & Silverman, 2011), and understanding of law (Umpstead, et al., 2013), and individual decision-making factors (Bagdasarov et al., 2015; Barrett et al., 2012) may be necessary. Such a multi-pronged approach could reverse the serious global problem of teacher misconduct.

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Measuring Solar Flux and Absorptivity

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ABSTRACT

The goal of this research was to evaluate the solar flux and absorptivity of an aluminum plate in Cedar City, Utah. This task was performed by first measuring the change in the temperature with respect to time for an 8"×10"×1/8" aluminum plate. Next, Matlab and Microsoft Excel software were utilized to analyze the data collected and determine the solar flux and absorptivity of aluminum 6061-T6. Solar flux measurements were compared with the solar flux measured at a solar plant nearby. The absorptivity of the aluminum plate, determined from the measurements taken, was compared with published values. The solar flux measured was determined to have an error of 16.9% and the absorptivity of the unpolished aluminum face was determined to have an error of 5.1%. After error analysis was performed using these results, it was determined that this approach of measuring solar flux and absorptivity could be improved to reduce the discrepancies with published data. The discrepancies were attributable to ignoring the parasitic heat loss to environment and not being able to repeat the experiment because of change of solar flux.

Table 1. Nomenclature for symbols used

Symbol	Name	Value
$C_{p(al)}$	Specific heat of aluminum (J/kg·K)	903 [1]
m	Mass of plate (kg)	
Q_{acc}	Heat accumulation (W)	
Q_{gen}	Heat generation (W)	
Q_{in}	Heat transferred in (W)	
Q_{out}	Heat transferred out (W)	
q''_{solar}	Solar flux (W/m ²)	
T_{plate}	Temperature of the plate (K)	
T_{sky}	Effective temperature of the sky (K)	261 [2-3]
t	Time (s)	
α_{paint}	Solar absorptivity of paint	0.96 [4]
α_{plate}	Solar absorptivity of aluminum plate	0.09 [1]
Δx_p	Thickness of the aluminum plate (in./m)	0.125/0.00317
ΔT	Change in temperature	
ε_{paint}	Emissivity of paint	0.88 [4]
ε_{plate}	Emissivity of aluminum plate	0.03 [1]
σ	Stefan-Boltzmann constant (W/m ² .K ⁴)	5.67×10 ⁻⁸ [1]
ρ_{al}	Density of aluminum (kg/m ³)	2702 [1]
τ_s	Solar transmissivity of glass	0.88 [1]

INTRODUCTION

The goal of this experiment was to familiarize the students with methods of heat transfer experimentation, numerical methods, and the analytical solution of radiation heat transfer. The experiment was based on the work of Martin et al. [5].

There were two purposes to this experiment. The first was to measure the solar flux in Cedar City, Utah, on a given time and day. The second purpose was to determine the solar flux measured and the absorptivity of the surface of a solid sheet of metal utilizing numerical methods. Matlab was used to evaluate the solar flux and absorptivity numerically.



Figure 2. (Left) Picture of experimental setup with black painted surface facing out. (Right) Picture of experimental setup with the aluminum surface facing out.

Test Procedure

1. Bring all equipment outside to a sunny area where no shadows will be cast for at least 30 minutes.
2. Attach the thermocouple to the center of the unpainted side of the aluminum plate with the electrical tape. Turn on the thermocouple.
3. Place the glass in the back of the picture frame. Make sure the side with the small pieces of insulation is facing back towards where the plate will be placed in Step 6. This step ensures that when the aluminum plate is put behind the glass, those small pieces of insulation are between it and the glass.
4. Cool the entire painted side of the aluminum plate with a bag of ice, not the ice directly. If the single bag of ice does not cover the entire plate, put some ice in sandwich bags and use these to fill in the gaps and completely cover the plate.
5. When the plate reaches approximately 40°F (according to the thermocouple), dry the aluminum plate with paper towels. During this time, the aluminum plate will immediately begin warming up, so Steps 6 and 7 should be completed before the plate reaches 65°F.
6. Place the plate on top of the glass with the black painted side facing the glass. Securely attach the insulation behind it using the duct tape. The plate should now be encased between the glass and the insulation with a negligible layer of air between the glass and the plate. Make sure the system is completely dry, inside and out, because any water will affect the rate at which the solar radiation will warm the plate.

7. Angle the front of the picture frame, with the aluminum plate installed in place, directly towards the sun. This can be done by pointing the dowel at the sun and adjusting the frame until the dowel no longer casts a shadow.
8. Beginning at 65°F, record the time for each increase of 1°F increase until the plate reaches 85°F.
9. Repeat Steps 4 to 8, this time cooling the unpainted side with ice and then placing the plate with that side facing out, as shown in Figure 2, and the thermocouple attached to the painted side of the plate.

ANALYTICAL SOLUTION

To obtain solar flux from experimental results, the basic governing equations for radiation heat transfer were used. When this experiment was performed, the results obtained were a relationship between temperature and time. For each temperature change, there was a change in time, or $\frac{dT}{dt}$. Therefore, to calculate solar flux, q'' , from experimental results, a relationship between $\frac{dT}{dt}$ and q'' must be determined. The First Law of Thermodynamics states [1]:

$$Q_{in} + Q_{gen} - Q_{out} = Q_{acc} \quad (1)$$

Taking the derivative with respect to time and dividing all terms by the surface area results in

$$q''_{in} - q''_{out} = q''_{acc} \quad (2)$$

This equation is rewritten for radiation heat transfer between an object and the sky in this manner for the painted side of the plate. When solving for the unpainted aluminum, α_{paint} and ε_{paint} are replaced with α_{plate} and ε_{plate} [1]:

$$\alpha_{paint} q''_{solar} + \varepsilon_{paint} \sigma T_{sky}^4 - \varepsilon_{paint} \sigma T_{plate}^4 = q''_{acc} \quad (3)$$

Because there was glass between the sun and the aluminum plate, the transmissivity of glass must be factored in for the first term. Equation (3) can then be rearranged as

$$\tau_s \alpha_{paint} q''_{solar} - \varepsilon_{paint} \sigma (T_{plate}^4 - T_{sky}^4) = q''_{acc} \quad (4)$$

Heat accumulated in a system, or Q_{acc} , is defined [1] as

$$Q_{acc} = m C_p \Delta T \quad (5)$$

Taking the derivative of Eq. (5) with respect to time and dividing it by surface area, the flux of heat accumulated by the system can be expressed as

$$q''_{acc} = \rho_{al} \Delta x_p C_{p(al)} \left(\frac{dT}{dt} \right) \quad (6)$$

Equations (4) and (6) can be combined. The result is

$$\tau_s \alpha_{paint} q''_{solar} - \varepsilon_{paint} \sigma (T_{plate}^4 - T_{sky}^4) = \rho_{al} \Delta x_p C_{p(al)} \left(\frac{dT}{dt} \right) \quad (7)$$

It should be noted that convection or conduction heat transfer on the plate can be ignored, since the front surface facing sun was insulated by a thin film of air with a very low conduction heat transfer coefficient ($k = 0.025$ W/m.K [1]) and the back of the plate was insulated by the insulation listed in Table 2. The heat transfer through this insulation was assumed to be zero. Since the plate was very thin (compared with its width and height) and the sides were insulated by the wooden frame, heat transfer was assumed to be one-dimensional. Any conduction gradient through the plate was negligible, because of the high conduction coefficient ($k = 237$ W/m.K) of aluminum [1] and the thickness of the plate compared to its width and length. Therefore, the plate itself was treated like an infinitely thin surface. For this reason, this experiment could be used to calculate the absorptivity of almost any highly conductive sheet material. The paint was assumed to have the same properties of being infinitely thin. Rearranging to isolate $\frac{dT}{dt}$ for Eq. (7) yields:

$$\frac{dT}{dt} = \frac{\tau_s \alpha_{paint} q''_{solar} - \varepsilon_{paint} \sigma (T_{plate}^4 - T_{sky}^4)}{\rho_{al} \Delta x_p C_{p(al)}} \quad (8)$$

This equation was numerically solved using Matlab for the corresponding times and temperatures of the plate to find solar flux and absorptivity of the plate. $C_{p(al)}$, ρ_{al} , τ_s , T_{sky} , σ , and Δx_p are all constants, and their values can be found in Table 1.

RESULTS

Part 1

Matlab was programmed to solve Eq. (8) using the q''_{solar} given by the solar plant in Parowan [6], an initial T_{plate} of 291.3 K (65°F), and an initial time of zero. This experiment was performed at 2:30 pm on November 28, 2017, in Cedar City, UT. Solar flux given by the solar plant for this time was 688 W/m². Also, emissivity and absorptivity of the carbon black paint was used for the numerical evaluation. Matlab was then

programmed to give a table of T_{plate} versus t with a time step of 1 second and export that table to an Excel spreadsheet. The theoretical results given by Matlab were plotted in Excel against the experimental results in Fig. 3. Experimental results are presented in Table 2. The program was also executed with a time step of 0.1 seconds, but the results were identical for these purposes, so the time step of 1 second is used throughout this experiment.

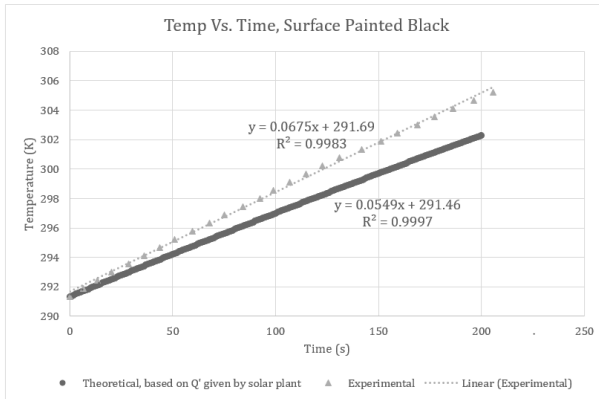


Figure 3. Theoretical evaluation versus experimental result.

Table 2. Experimental data for black painted surface			
t (s)	dt (s)	T (°F)	T (K)
0	0	65	291.3333
6.51	6.51	66	291.8889
13.46	6.95	67	292.4444
20.31	6.85	68	293
28.47	8.16	69	293.5556
43.8	7.64	71	294.6667
50.8	7	72	295.2222
59.54	8.74	73	295.7778
67.88	8.34	74	296.3333
75.08	7.2	75	296.8889
84.07	8.99	76	297.4444
92.54	8.47	77	298
98.76	6.22	78	298.5556
114.6	7.75	80	299.6667
122.71	8.11	81	300.2222
130.87	8.16	82	300.7778
151.36	9.38	84	301.8889
159.15	7.79	85	302.4444

To match q''_{solar} reported at the plant, the q''_{solar} was changed in Matlab, in Eq. (8), until the slope of the numerical result was equal to the slope of the trendline of the experimental results ($\frac{dT}{dt}$), as shown in Fig. 4. Thus, by changing the q''_{solar} until the two slopes are equal, q''_{solar} was found by numerical iteration.

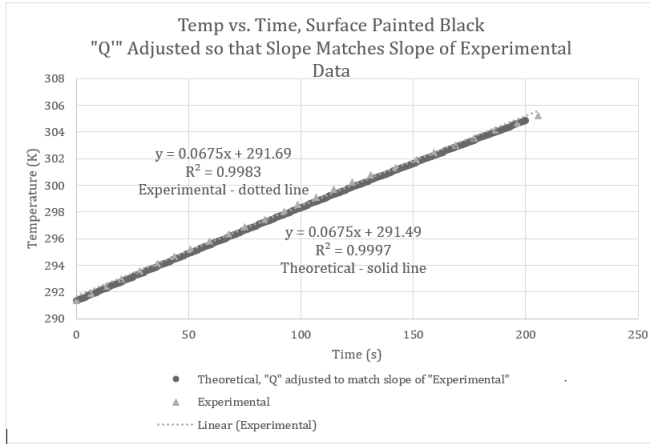


Figure 4. q''_{solar} of Matlab program vs. the slope of the trendline of the experimental results.

The q''_{solar} that produced the same slope as the slope of the experimental results was the experimental solar flux. The solar flux calculated was 804 W/m^2 . Using Eq. (9), it was determined that the experimental solar flux had 16.9% error from the solar flux given by the solar plant in Parowan.

$$\% \text{ error} = \frac{\text{theoretical} - \text{experimental}}{\text{theoretical}} * 100\% \quad (8)$$

Part 2

Using the value of q''_{solar} evaluated by trial and error in Part 1 (804 W/m^2), the absorptivity of the aluminum was determined. The emissivity value was first changed to the emissivity value of aluminum, presented in Table 1. Matlab was again used to evaluate the theoretical temperatures of the plate at their respective times and the data points were compared to the real temperature-versus-time data, presented in Table 3. This comparison is shown in Figure 5.

Table 3. Experimental results for unpainted aluminum surface			
t (s)	dt (s)	T (°F)	T (K)
0	0	65	291.3333
18.46	18.46	66	291.8889
68.92	22.43	68	293
117.73	21.31	70	294.1111
143.26	25.53	71	294.6667
171.6	28.34	72	295.2222
201	29.4	73	295.7778
282.52	39.68	75	296.8889
324.8	42.28	76	297.4444
367.5	42.7	77	298
465.5	52.07	79	299.1111
514.49	48.99	80	299.6667
564.46	49.97	81	300.2222
641.76	77.3	82	300.7778
812.12	69.32	84	301.8889
887.75	75.63	85	302.4444

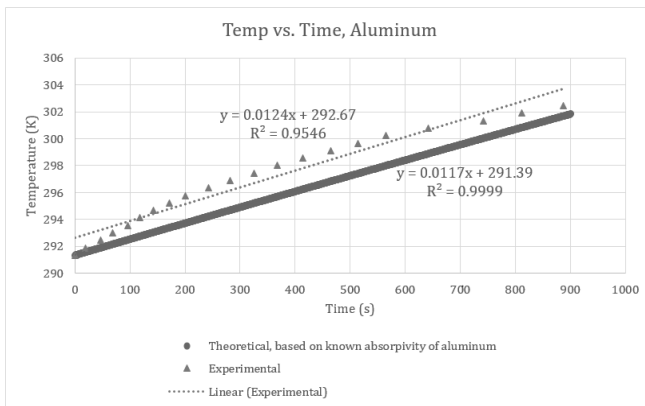


Figure 5. Theoretical evaluation versus experimental result to evaluate absorptivity of aluminum.

The absorptivity was then adjusted in Matlab until the slope is equal to the slope of the trendline of the experimental results, similar to the process used in part one. The q''_{solar} , however, was kept the same as the q''_{solar} (804 W/m²) evaluated in part one. Only absorptivity was changed. The absorptivity that gave a matching trendline was then the

absorptivity of aluminum. The results for experimental absorptivity can be seen in Figure 6.

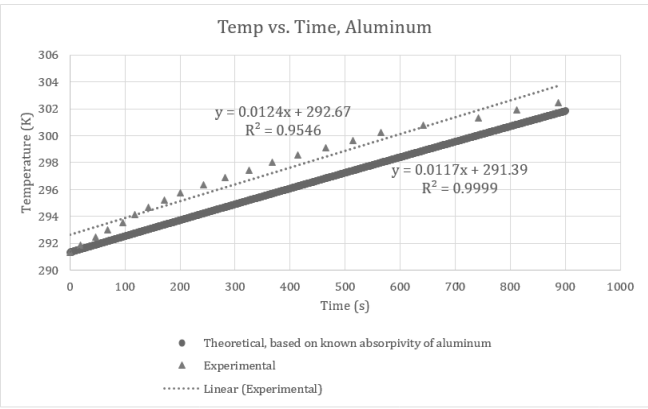


Figure 6. Corrected aluminum absorptivity to fit slope of experimental data.

The absorptivity “ α ” found was the experimental absorptivity. The absorptivity found was 0.158. The published absorptivity of an aluminum surface, not polished, is 0.15, as stated in Table 1. Therefore, the error according to Eq. (9) is 5.1% error.

ERROR ANALYSIS

It is interesting to note that the error of the absorptivity found in Part 2 was much smaller than the error for solar flux found in Part 1. This would suggest that, perhaps, the solar flux found in the experiment was in fact close to the actual solar flux in Cedar City, Utah, at that time. The large deviation in the solar flux found from the solar flux given by the solar plant in Parowan seems to point to the possibility that the two cities did, in fact, have a larger difference in solar flux that day than anticipated, and it may not necessarily mean that the experiment was not valid. Another reason for the deviation between the two solar fluxes is that the solar plates in Parowan follow the sun through its daily course, but only along the east-to-west axis. The panels do not point north or south at all at any time. Therefore, during the winter time, the sun is never directly overhead but is always in the southern hemisphere. As a result, the sun will never hit these plates at an angle that is normal to their surface. Since the plate in this experiment was facing the sun exactly, it was expected that it would measure a higher solar flux because of the solar irradiation hitting the plate more directly. Since the error in the absorptivity found experimentally is 5.1%, it can be said that this experiment was valid for

measuring the absorptivity of an aluminum face. The error could have been caused by the aluminum being used having slightly different properties than the aluminum used to find the known absorptivity value of aluminum. Martin et al. [5] (p. 745) gives the value for polished aluminum to be 0.09. However, the aluminum used in this experiment was not polished, and unpolished aluminum can have absorptivity of up to 0.15 [1]. It is unknown exactly where the aluminum used in this experiment falls in this range. Some error can be attributed to error in the thermocouple used. This was the cause of the deviation of the data points for the experimental data from their trendline, thus causing a somewhat low R^2 value of 0.95 in Part 2. This error did affect the experiment in a small way, but since the slope of the line was what was in question, it was not a critical error. Also, the discrepancy may be attributable to ignoring the parasitic heat loss to environment and not being able to repeat the experiment because of change of solar flux.

CONCLUSION

The goal of conducting this experiment was to determine a method of measuring and determining solar flux at a location and then to use this information to determine the absorptivity of T6-6061 aluminum. The second goal was to develop the simplest method possible for others to be able to replicate similar results elsewhere.

From the results, it was determined that the day the experiment was conducted, the solar flux in the Cedar City, Utah, area was 804 W/m^2 . When the experimental results were compared with the value at a local solar facility (688 W/m^2), it had a variance of approximately 16.9%. Several factors contributed to this relatively large error. The surface of the solar cells at the local facility are set at a fixed angle that is not normal to the incoming solar irradiation, so the solar cells did not absorb exactly the same amount of solar irradiation as the plate in the experiment. Another problem is the time of year that the experiment was carried out. The ideal time of year to measure solar energy is during the summer months, because this is when the sun is the highest overhead. These are one or two considerations that can be taken into account in the future.

Using the solar flux value that was determined in this experiment and the accompanying data from the unpainted side of the aluminum plate, the absorptivity of the aluminum was found to be 0.158. In this experiment, unpolished aluminum was used, which has a published value of 0.15. The variance between the experimentally determined value and the published value was only 5.1%. This is significantly smaller than the

variance in the solar flux value, but this discrepancy can be reduced further if the initial solar flux value that is determined is optimized by the considerations discussed in this section.

Overall, these values were reasonably accurate for the simplicity of the setup that was utilized, with a 16.9% error in solar flux and a 5.1% error in absorptivity. With a few adjustments, the setup and system can be optimized to give more accurate readings that were produced in this experiment. Because of the simplicity of this setup, these results can be replicated by many others.

ACKNOWLEDGMENTS

This project would not have been possible without the support of the the Department of Engineering and Technology provided financial support for some key pieces of equipment and technical expertise from the professors and instructors in the department.

We would also like to thank the Utah NASA Space Grant Consortium for additional funding and support. Barbara Rodriguez and Jamie Campbell were integral in helping us to navigate the purchasing equipment and supplies.

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Simple Experimental, Analytical, and Numerical Methods to Evaluate the Deflection of a Beam

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ABSTRACT

In engineering applications, when different components such as beams, columns, or foundations are used, they are normally designed within certain elastic limits. These limitations are based on considerations such as the safety factor, environment, loads, allowable stress, deflection, and mechanical properties of the material. In the case of beams, the design of such beams can be complex but is intended to ensure the beam can safely carry the required load. In a previous paper, a device was designed and constructed to evaluate the elastic deflection of a beam. The paper discussed the fundamentals of beam deflection and a simple, cost-effective method (integration method) to evaluate the amount of deflection and the slope at the free end of a beam. The purpose of this paper is to expand the research by investigating both analytically and experimentally the fundamentals associated with four beams made from copper, steel, bronze, and aluminum. The analytical results from this experiment were compared with the finite element method by utilizing SolidWorks Simulation. All characteristics of the experiment—such as gravity,

length, width, thickness, and material properties—were considered in the simulation. This investigation demonstrated that the experimental values and published values match within 95%.

INTRODUCTION

Structures cannot be created without engineering theory, and design rules have existed from the earliest times for building structures such as Greek temples, Roman aqueducts, and Gothic cathedrals—and later for steel skyscrapers and the frames for aircraft. In the 17th century, Galileo was the first to introduce recognizably modern science into the calculation of structures; he determined the breaking strength of beams. But with the discovery of “The Codex Madrid” in the National Library of Spain in 1967, it was found that Leonardo da Vinci’s work (published in 1493) had not only preceded Galileo’s work by over 100 years, but had also, unlike Galileo, correctly identified the stress and strain distribution across a section in bending [1].

In the 18th century, engineers moved away from this “ultimate load” approach, and early in the 19th century, a formal philosophy of design had been established—a structure should remain elastic, with a safety factor on stress built into the analysis. This philosophy held sway for over a century, until the first tests on real structures showed that the stresses confidently calculated by designers could not actually be measured in practice. Structural engineering has taken a completely different path since the middle of the 20th century; plastic analysis reverts to Galileo’s objective of the calculation of ultimate strength, and powerful new theorems now underpin the activities of the structural engineer [2]. (For the history of beam deflection, refer to *History of Strength of Materials* by Stephen P. Timoshenko [3].)

In some engineering problems, the maximum load, in the elastic region, may not be a restriction, but the amount of deflection under operation is. The deflection of a beam must often be limited to provide integrity and stability to the structure. The beams may be made from steel, aluminum, timber, or reinforced concrete and have a cross-sectional shape that may be rectangular, C channel, T-shaped or I-shaped. The design of such beams can become complex but is imperative for the beam to safely carry the required load.

THEORY OF DEFLECTION

In this analysis, the following assumptions are undertaken to present the fundamental relationship between loads and deflections.

- The beam is in a horizontal position.
- The beam support is cantilever, fixed on one end and free on the other end.
- The weight of the beam has minimal effect on the beam deflection.
- The equation is valid only for beams that are not stressed beyond the elastic limit.
- The deflection and the deflection angle of the loaded beam are small (less than a few degrees).

The cantilever beam shown in Figure 1, under the end load P , is deflected in the elastic region. The relationship between the end deflection (v_A) and the force (P) may be expressed as [4, p. 582]:

$$v_A = \frac{PL^3}{3EI} \quad (1)$$

where L is the length of the beam (m), E is the modulus of elasticity of the solid beam (N/m^2 or Pa), and I is the geometric property, area moment of inertia (m^4).

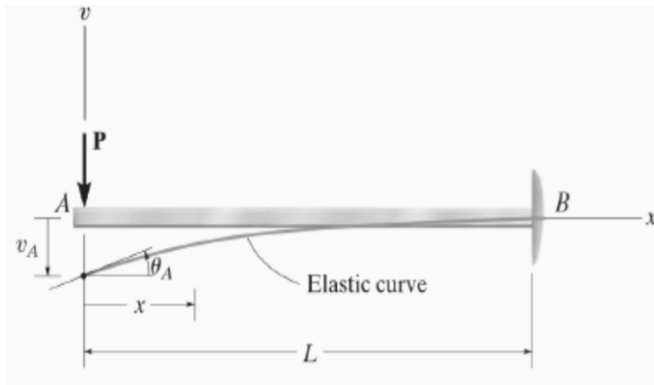


Figure 1. Cantilever beam under an end load P [1, p. 582].

The modulus of elasticity, which is a property of the beam, is presented in Table 1 for several materials. For a beam with a rectangular cross-sectional area, I is defined as [2]:

$$I = \frac{1}{12}bh^3 \quad (2)$$

where b is the width of the beam (m), and h is the height (thickness) of the beam (m).

Table 1. Modulus of elasticity of common structural material [4]				
Material	Steel A-36	Aluminum 6061-T6	Copper	Brass
Modulus of elasticity (N/m ²)	200×10 ⁹	69×10 ⁹	115×10 ⁹	95×10 ⁹

EXPERIMENT

Four types of beam materials were used (steel, aluminum, copper, and brass) for the experiment. This experiment is not limited to the suggested beam materials; any elastic beam may be selected to perform the experiment. The experiment apparatus is presented in Figure 2.

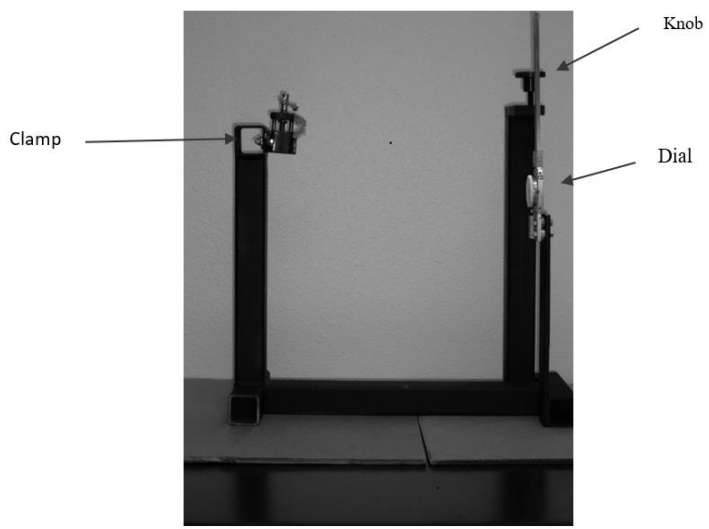


Figure 2. Experiment apparatus.

The experiment was performed for each material listed previously. The averages of these experiments are presented in Table 2.

Table 2. Beam material and dimensions			
Material	L (m)	b (m)	h (m)
Steel	0.290	0.0026	0.0030
Aluminum	0.302	0.0249	0.0033
Copper	0.301	0.0254	0.0032
Brass	0.301	0.047	0.0033

Beam Deflection with Known Weight

In this section, with a known mass, the deflection distance was measured and analytically evaluated. A beam from Table 1 was selected. The beam was placed (the end without the hole) horizontally into the clamp, and the clamp was tightened. The following dimensions shown in Figure 3 were measured: length (L), width (b), and height (h). The measurements were taken three times, and the average values were used for the final calculations (Table 2). Note that “ L ” was measured from the center of the hole to the edge of the clamp.

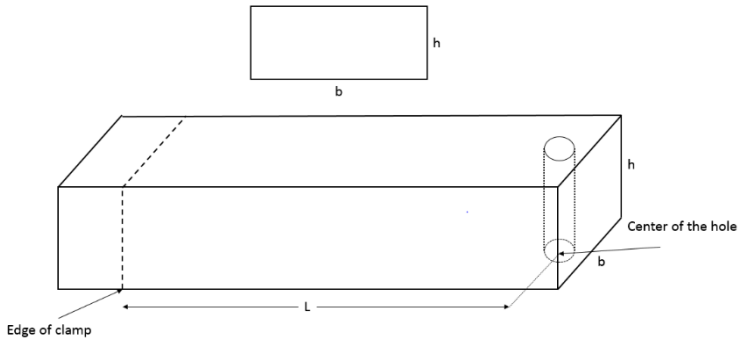


Figure 3. Beam dimensions.

Masses were added to the free end of the beam to have approximately 0.5 inches of deflection. The total mass (m) was then recorded in Table 3. This task was performed three times, and the average value was used for the final calculations.

Table 3. Measured behavior of the beam under load P		
Material	Total mass (kg)	Deflection (m)
Steel	2	0.01346
Aluminum	0.621	0.0127
Copper	0.98	0.0127
Brass	0.632	0.0127

Analytical Approach

Beam deflection with known weight utilizing the integration method is presented in this section.

The total weight or force (w or P) were evaluated using

$$P=w=mg \quad (4)$$

where P (or w) is the weight or load (Newton), m is mass (kg), and g is the gravitational acceleration of earth (9.81 m/s^2). The result is recorded in Table 4.

The end deflection (v_A) was calculated using Eq. (1). The result is also recorded in Table 4.

Table 4. Calculated values of beam behavior under the load			
Material	Weight (N)	Deflection V_A (m)	Experimental % Error
Steel	19.62	0.0139	3.17
Aluminum	6.09	0.01346	10.9
Copper	9.61	0.01193	7.2
Brass	6.2	0.0094	12.3

RESULTS/ANALYSIS

The experiment performed as expected with the beam undergoing a small deflection and returning to its original shape without any permanent deformation. Table 4 shows the percent error for the deflection V_A ranges from 3.17% to 12.3%. These relatively low errors show the accuracy of the inexpensive apparatus discussed in the previous paper, while also proving the theory of beam deflection under the stated assumptions. Further sources of error are discussed in the “Sources of Error” section of this paper.

SolidWorks Simulation

SolidWorks utilized the Finite Element Method to determine the deflection along the cantilever beam. A beam was first modelled in SolidWorks to simulate each beam that was used experimentally. The length, width, and thickness of each beam was considered in the simulation. SolidWorks also takes into consideration gravity, applied force, and the physical properties of the material. The beam was fixed at one end and a force was applied at the free end, providing an accurate representation of the performed experiment. The simulation was performed for each material (steel, aluminum, copper, and brass), and the maximum deflection of each material was recorded in Table 5 and Figures 4–7.

Table 5. SolidWorks Simulation values of beam behavior under the load			
Material	Weight (N)	Deflection V _A (m)	Experimental % Error
Steel	19.62	0.01360	1
Aluminum	6.09	0.01081	11
Copper	9.61	0.01208	1
Brass	6.2	0.0089	5

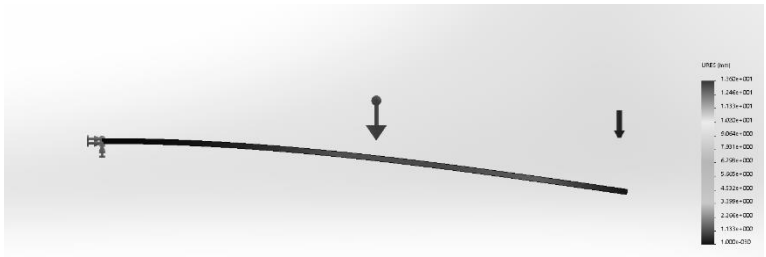


Figure 4. A-36 Steel SolidWorks deflection (mm).

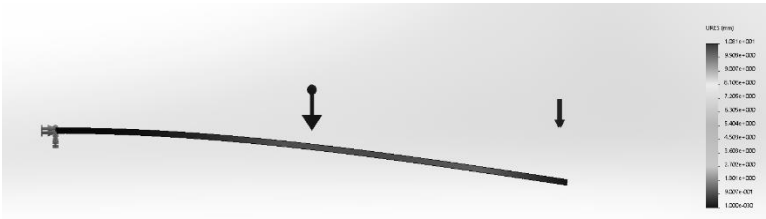


Figure 5. 6061-T6 Aluminum SolidWorks deflection (mm).

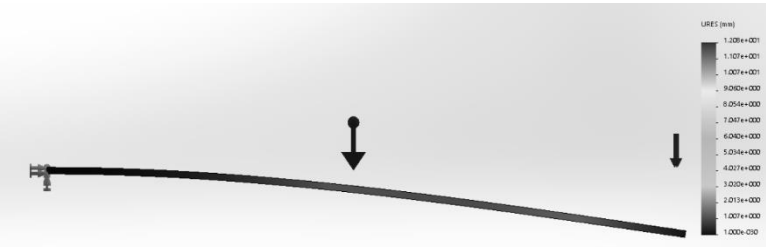


Figure 6. Copper SolidWorks deflection (mm).

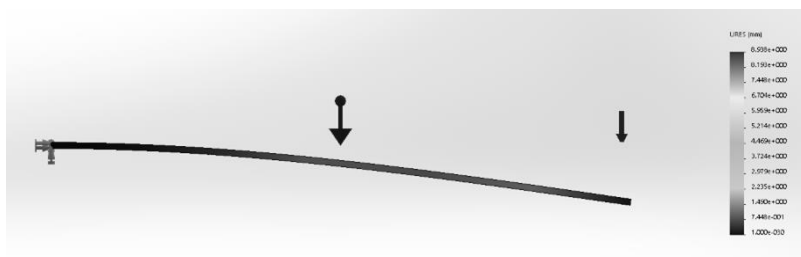


Figure 7. Brass SolidWorks deflection (mm).

Results/Analysis Simulation

It can be seen from Table 5 that the percent error for the deflection V_A ranges from 1% to 11% when comparing the simulation with the experimental results. The accuracy of the simulation is largely dependent on the accuracy of the measurements used to describe the beam. Some of the simulations have a large percent error (around 10%), likely because of the accuracy of measuring the material. These percent errors show that there is validity to the inexpensive apparatus (less than \$200) designed and constructed at SUU.

The simulations also give a greater understanding of the theory of beam deflection, using color to demonstrate the severity of the bend over the length of the beam. This gives a greater understanding of how materials deflect near a fixed end as well as at the free end. Further sources of error are discussed in the “Sources of Error” sections of this paper.

Sources of Error

When performing experiments, there will always be some errors. Sources of error might result from one or more of the following:

1. Specimen fabrication. A sample might have been fabricated on a humid, hot, and windy day. Then, the next sample was fabricated on a dry, cold, and calm day. Therefore, two identical samples may have the same composition but behave differently if the fabrication was not identical.
2. Specimen composition. When the material compositions of two batches of the specimen are not identical, the discrepancy in the composition may cause different behavior under the same load condition.

3. Test method. When evaluating the same mechanical properties of a specimen, there may exist several methods, including bending, twisting, or shearing the specimen. Therefore, if the same method of testing is not performed, the results may be different.
4. Operator bias. If two operators are performing the same test, the results may be different based on their measurement accuracy, the time spent to perform the test, etc.
5. Calibration. If the instrument utilized to measure a mechanical property is not calibrated, the result may not be accurate.

A large source of error in this experiment is the operator bias and the test method. The experiment was performed by a human and may not have been executed as accurately as possible. Another source of error worth noting is the inaccuracy of the weight measurements. For example, the weight claimed to be 100 g but was later weighed at about 99.1 g.

CONCLUSION

Throughout this paper, the theory of beam deflection has been explained and used. The equations presented, experiments done, and simulations performed prove the importance of knowing and understanding how beams act under a vertical load. It shows that as beams are deflected within the elastic limit they will return to their original shape without any permanent deformation. It provides greater insight into the practical applications of beam deflection. These fundamental principles are what have literally built our society—without the knowledge of beam deflection, skyscrapers would not be possible and bridges would collapse. This experiment shows how simple it is to gain a basic understanding of the fundamentals of beam deflection on a relatively low budget.

ACKNOWLEDGMENTS

The funding was partially supported by the Engineering & Technology Department, and the Department of Workforce Services Grant entitled “STEM Career Paths to Success.” This grant was awarded to Dr. Richard Cozzens (Professor of Engineering Technology at Southern Utah University) during the 2015-2016 academic year. We would also like to thank the Utah NASA Space Grant Consortium for additional funding and support.

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A Simple Steady-State Experimental Method to Determine the Thermal Conductivity of Solid Plate

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ABSTRACT

This paper discusses the fundamentals of conduction heat transfer and gives greater insight into a third-generation experiment, performed at Southern Utah University, to measure the thermal conductivity of solids. The method used to determine the thermal conductivity is a one-dimensional steady-state conduction heat transfer approach. The thermal conductivity of ultra-high-molecular-weight polyethylene (UHMW, TIVAR H.O.T.) was experimentally determined and compared with the published value. The results from a local company, GAF, indicate that the thermal conductivity of the test material may not have actually been 0.4 (W/m.K) as provided in the literature. Further experimentation on materials with certified thermal conductivity values may be performed to validate the accuracy of the test apparatus.

INTRODUCTION

Measuring thermal conductivity of solids accurately is very important in the field of heat transfer. Traditionally, as it will be presented,

steady-state methods determine thermal conductivity using the Fourier heat conduction law, from the relationship between heat flow rate and an applied temperature difference. Although theoretically, it appears to be simple, in reality, achieving high accuracies with steady-state heat conduction methods is extremely challenging and requires very accurate temperature sensors and parasitic heat loss consideration.

Kraemer and Chen used a differential steady-state method in their conduction heat transfer experiment to account for parasitic heat loss, but still gained some error percentages because of radiation [1]. The heat transfer team from Fall 2016 at Southern Utah University (SUU) used a $10.5'' \times 10.5'' \times 0.125''$ aluminum plate as a conductive medium. This material was chosen to reduce the amount of time the experiment took to reach steady state, but the temperature difference was so small that the experiment failed [2]. Several complicated and not cost-effective methods exist that are not suited for undergraduate research [3-9]. Those methods are beyond the scope of this project and will not be discussed.

This paper discusses the fundamentals of conduction heat transfer and gives greater insight into a third-generation experiment, performed at SUU, to measure the thermal conductivity of solids. The method used to determine the thermal conductivity is a one-dimensional steady-state conduction heat transfer approach. The thermal conductivity of ultra-high-molecular-weight polyethylene (UHMW, TIVAR H.O.T.) was experimentally determined and compared with the published value. Three independent tests were performed as part of this experiment. However, the apparatus that was designed and built can be used to experimentally determine the thermal conductivity of other solids.

This paper will consist of a background, equipment, cost, and construction sections, which apply to each trial. The paper will then break into several parts to discuss the procedures, data, results, and discussion for each test. Finally, an uncertainty analysis and conclusion will state the findings of the experiment.

BACKGROUND

Conduction heat transfer is one of three ways in which heat is transferred. It occurs when energy transfers from highly energized particles to less energetic particles through a solid material. The equation for steady-state, one-dimensional heat conduction through a plane wall, presented in Eq. (1), was derived by the French mathematician, Jean Baptiste Joseph Fourier [10]. It has since been known as Fourier's law of heat conduction.

$$\dot{Q} = -\frac{kA\Delta T}{\Delta x} \quad (1)$$

where $\dot{Q}$ represents the heat transfer rate (W), k is the thermal conductivity of the material ($\frac{W}{m.K}$), ΔT is the change in temperature (K), and Δx is the thickness of the material (m). The negative sign in this equation is due to the temperature difference and the direction of heat transfer. In the equation, ΔT represents $(T_2 - T_1)$, which will result in a negative value. Hence, the minus sign is added to result in a correct heat transfer direction. This equation will be used to determine the thermal conductivity of UHMW in this experiment.

EQUIPMENT

- Insulated Box- 2" R10 Insulation
 - Measuring and cutting tools
 - Caulking gun
- 16-5 Ohm ceramic resistors
- 25-thermistors DS18B20
- Arduino UNO board
- Wire
 - Solder
 - Flux
- Laptop
- Power supply
- Multimeter
- 12"-square UHMW
- Kapton tape
- 2-channel relay

ASSUMPTIONS

1. No convection occurs inside or outside the system.
2. Once the system reaches steady state, all of the heat ($\dot{Q}$) from the resistors will be conducting through the two UHMW plane walls.
3. One-dimensional conduction heat transfer.
4. No heat transfer through the 2" R10 insulation.

COST

The following price list shown in Table 1 is based off prices found on Amazon.com.

Table 1. Component prices	
ITEM	COST (\$)
Thermistors	50
Arduino board	11
Kapton tape	8
12"-square UHMW (2)	50
2-channel relay	7
Total	126

CONDUCTION HEAT TRANSFER SYSTEM

In the first of the system design, the test apparatus was designed utilizing SolidWorks, a 3D modeling program. This initial design is shown in Fig. 1.

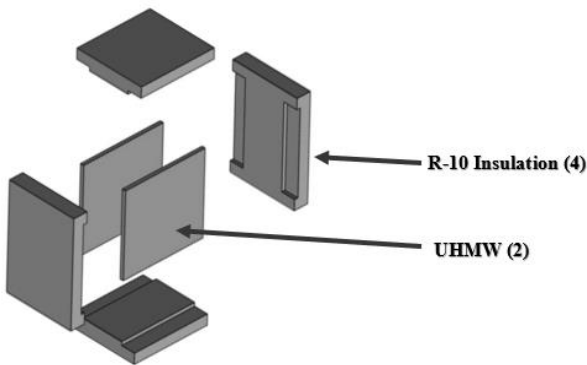


Figure 1. SolidWorks model of apparatus with UHMW plates and R-10 walls.

Later, resistors were laid out along the length of the UHMW to provide uniform heating. For this experiment, 40 W was selected as a starting power input (Q). The wattage was adjusted up or down to accommodate the time restraint for reaching steady state without melting the insulation. Table 2 depicts how this was performed by applying Ohm’s Law and summation of resistance (R) in series and parallel. The power supply’s capability of 3 amps (I) and 15 volts (V) with the desired 40 W limits the resistance range to approximately 4.2 to 5.6 Ohms.

Table 2. Resistance, voltage, and current values for desired power output			
Q (W)	V (V)	R (Ω)	I (A)
40	1	0.025	40.000
40	2	0.100	20.000
40	3	0.225	13.333
40	4	0.400	10.000
40	5	0.625	8.000
40	6	0.900	6.667
40	7	1.225	5.714
40	8	1.600	5.000
40	9	2.025	4.444
40	10	2.500	4.000
40	11	3.025	3.636
40	12	3.600	3.333
40	13	4.225	3.077
40	14	4.900	2.857
40	15	5.625	2.667
40	16	6.400	2.500
40	17	7.225	2.353

A multimeter was used to read the current through the circuit of resistors. The power supply was used to provide voltage to the circuit. With these readings, the power (heat) was calculated using Eq. (2).

$$P = V * I \quad (2)$$

Two pairs of ceramic resistors were wired together in parallel. Each group of four resistors was wired to another in series resulting in a total resistance of 5 Ohms. The entire configuration is shown in Figure 2A.

The R-10 insulation was cut to create a box that can fit a 0.3048×0.3048 -m (12×12 in) sheet of UHMW. This resulted in an interior surface area of the UHMW of 0.076 m^2 for heat to transfer through. The insulation box is shown in Figure 2B.

The resistors were suspended inside the box using wooden dowels placed at the top and bottom to prevent them from coming in direct contact with the insulation. Figure 2C shows the wooden dowels and the suspended resistors.

Thermistors were placed at the top center and bottom center of the box. These thermistors were used to read the ambient temperature of the air inside the box. The thermistors were connected to an Arduino [11]. The Arduino interpreted the raw data and exported the data to an Excel spreadsheet in degrees Celsius. Thermistors were attached each side of the UHMW using Kapton tape. There will be a thermistor on each corner and in the center on the inside and outside surface of the UHMW as shown in Figure 2D.

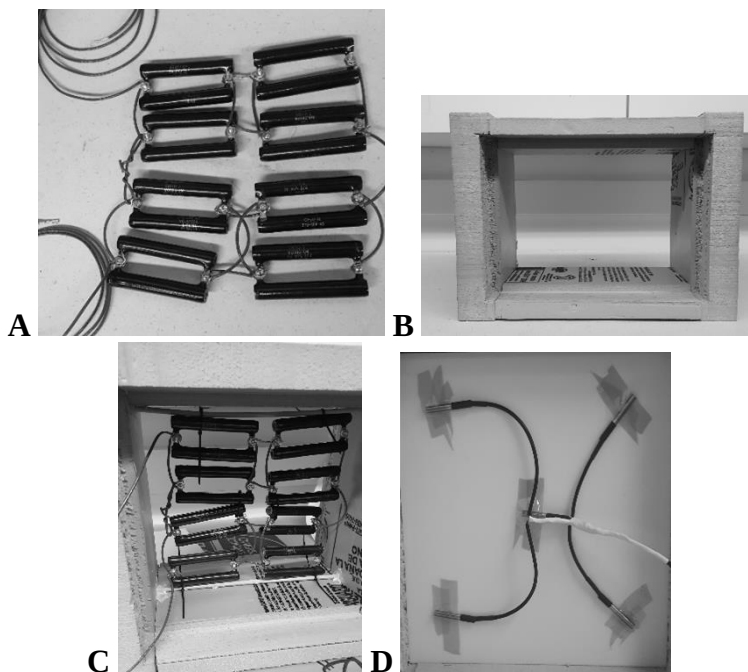


Figure 2. (A) Resistor configuration; (B) R10 Insulation assembled. (C) The resistor configuration suspended on wooden dowels. (D) Thermistor locations on UHMW. Test Method - Thermal Conductivity

Using the test apparatus, the thermal conductivity of UHMW was determined. This section outlines the steps taken to use the apparatus to obtain the data needed to calculate the thermal conductivity.

1. A power supply and multimeter were connected in series to the resistor pack. The power supply was set to 15 V (Table 2).

2. The Arduino was set to report data points at one-minute intervals.
3. The experiment was terminated when surface temperatures of the UHMW were no longer changing (the testing apparatus reached steady state). It should be noted that since UHMW has a low thermal conductivity, it took several hours for it to reach steady state [12].
4. Using Eq. (2), the power input to the testing apparatus was calculated using the measured voltage from the power supply and current values from the multimeter. The voltage on the power supply was adjusted to achieve the desired power input of 40 W.
5. Eq. (1) and the average steady-state temperatures for the inner and outer surfaces of the UHMW were used to calculate its thermal conductivity.

Trial One

The first trial was conducted using the configuration shown in Figure 3 with the thermistor configuration shown in Figure 4. Each X in the figure represents a thermistor location. In the final setup, the insulation has resistors and thermistors inside, the UHMW has thermistors on each side, and all wires are connected to the Arduino or power supply. This experiment took 5 hours to reach steady state with an input of 40 W. It was determined that steady state was achieved when there was no longer a change in the average thermistor reading on each surface for 30 minutes.

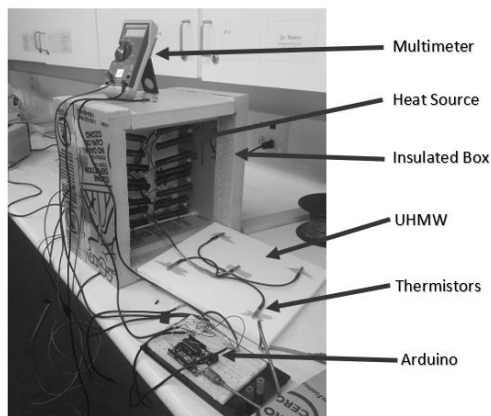


Figure 3. Trial one setup of test apparatus.

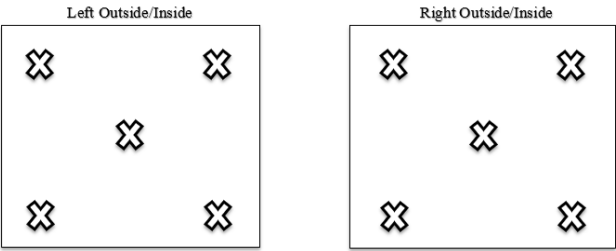


Figure 4. Thermistor configuration used.

Results

The data collected showed a significant temperature difference across the plastic on both sides of the box, which is an indication that everything in the test apparatus is working. The trends in temperature difference over time for the inside and outside of the left and right sheets of UHMW are shown in Fig. 5.

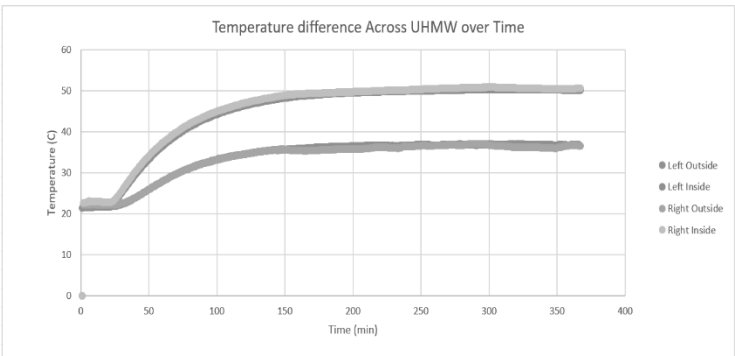


Figure 5. The increase in temperature over time in UHMW.

The results from the first trial are shown in Table 3. This includes the average change in temperature taken after the apparatus reached steady state, as well as calculations for thermal conductivity of UHMW and the percent error based on the published value of $0.4 \frac{W}{m.k}$ [12].

Table 3. Results from the first trial						
Side	ΔT ($^{\circ}C$)	Q (W)	2A (m^2)	ΔX (m)	k ($\frac{w}{m.k}$)	Percent error
Left	12.28	40	0.152	0.0127	0.272	32.0
Right	12.99	40	0.152	0.0127	0.257	35.

Discussion

The high percent error in the first trial, presented in Table 3, might be due to natural convection occurring in the two 3-inch sections between the ceramic resistors and the UHMW. The other source of inaccuracy was attributed to the parasitic heat loss. To minimize the parasitic heat loss and reduce the convection heat transfer, another sheet of insulation was added against one side of the resistors, and the apparatus was set flat on more insulation. In this configuration, only one UHMW sheet will be exposed and will be facing upwards. This will cause all of the 40 W of heat to transfer through the upper sheet. This will reduce the volume of air inside the box, reducing the natural convection heat transfer. This will not totally eliminate natural convection, but it will certainly reduce the effects of it.

In Trial 1, it was seen that the heat was rising from the bottom of the box to the top of the box due to natural convection. This caused an uneven distribution of temperature on the UHMW sheets. This could have then caused a higher percent error in the calculations because of the inability of the test apparatus to tell how much wattage went to each section of the sheet. Hence, by tilting the apparatus on its side into a horizontal position, it will reduce the volume of air in the box, which reduces the natural convection but then also makes use of the natural convection that will happen to keep the majority of the plate is at a more even temperature. These effects are what led to Trial 2 and the change in setup, as seen in Figure 6. However natural convection does not give a full explanation of the 35% error.

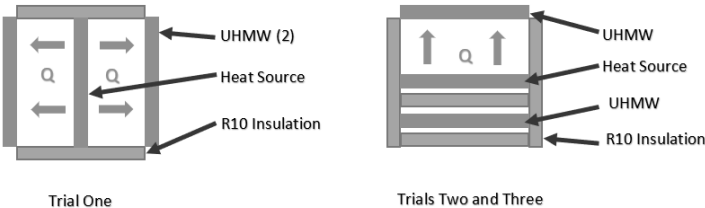


Figure 6. Apparatus orientation for Trials 1, 2, and 3.

Trial Two

In this new set-up, one of the UHMW sheets was replaced with 2” R10 Insulation and the box was laid down as shown in Figure 7 with the thermistor configuration shown in Figure 4. This configuration was used for the rest of the trials. This was done in an attempt to reduce some of the error from Trial 1. Further explanations are contained in the results and discussion sections under Trial 2.

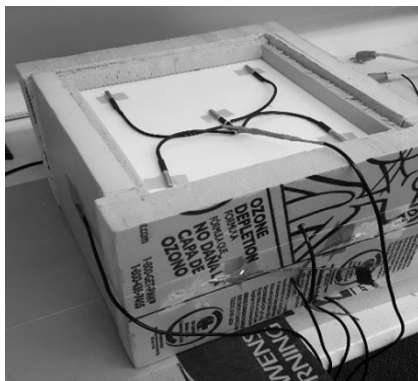


Figure 7. Trial 2 testing apparatus.

Results

Trial 2 reached steady state in 4 hours. The temperature increase with time is shown in Figures 8 and 9. Figure 8 shows the temperature variation on the inside surface of the UHMW. Figure 9 shows the temperature variation on the outside surface of the UHMW and that the outside of the UHMW does not have as smooth of a steady-state temperature. This may be due to its exposure to outside convection. Figures 8 and 9 show that the inside and outside surfaces of the UHMW were not evenly heated with the center being the highest temperature.

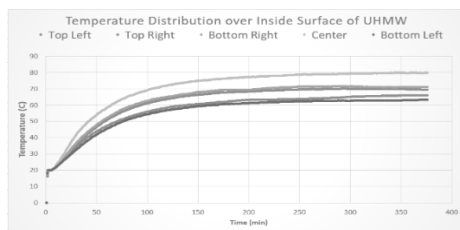


Figure 8. Temperature distribution over the INSIDE surface of the top UHMW.

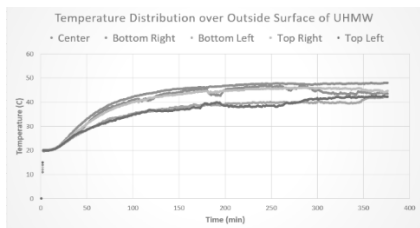


Figure 9. Temperature distribution over the top OUTSIDE surface of the UHMW.

Figure 10 shows the temperature difference across the UHMW from the inside to the outside surfaces. This will be the temperature difference used in the calculations for thermal conductivity.

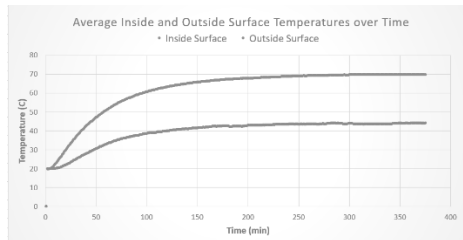


Figure 10. The temperature difference from the inside surface to the outside surface.

In this test, it was assumed that all the heat would transfer through the upper sheet of UHMW. However, thermistors recorded a 10°C variance across each side of the upper UHMW sheet. The bottom sheet of UHMW also had a slight rise in temperature, which means that the insulation is not perfect. However, the ΔT was 0.01°C and can be considered negligible. After the experiment reached steady state, the ceramic resistors were checked to make sure they had all heated up. All ceramic resistors were similarly heated up, which leads to the belief that the apparatus was still functioning properly, even though each side of UHMW had a 10°C range in temperatures. Therefore, the data were used to make new calculations, which are shown in Table 4.

Table 4. Results from the second trial					
ΔT (°C)	Q (W)	$2A$ (m ²)	ΔX (m)	K (W/m.K)	Percent error
25.89	40	0.076	0.0127	0.258	35.5

Discussion

With the new configuration, there was a 35% error. This suggests that natural convection is not the source of error. One hypothesis for the high percent error is that most plastics' thermal conductivity changes with a change in temperature. Upon research, there are no published results for the effects of temperature on the thermal conductivity of UHMW. To determine whether this is the cause of inaccuracy, the input wattage was reduced by half. This will result in an overall smaller rise in temperature of the plastic and will reduce the parasitic heat loss. If the thermal conductivity was changing with temperature, it will certainly affect the percent error. The percent error should be smaller. However, that was not the result of Trial 3.

Trial Three

A third trial was conducted with half the wattage input to investigate whether the percent error would decrease. This trial was based on the assumption that the thermal conductivity of UHMW was changing with the increase in temperature.

Results

The results of Trial 2 indicated a thermal conductivity value of 0.258 (W/m.K). When this value is used with the known thickness, area, and temperature difference to solve for $\dot{Q}$, the resulting input wattage was around 60 W—1.5 times larger than the actual input wattage. If a smaller percent error were achieved when applying a lower wattage, these results would support this assumption. Each temperature from the thermistors at each time value was averaged for the outside and the inside of the plate and each was plotted with respect to time as shown in Figure 11. A jump can be seen at the end of the data. This indicates the sample may not have reached a sufficient steady state and will be further explored in the discussion section under Trial 3.

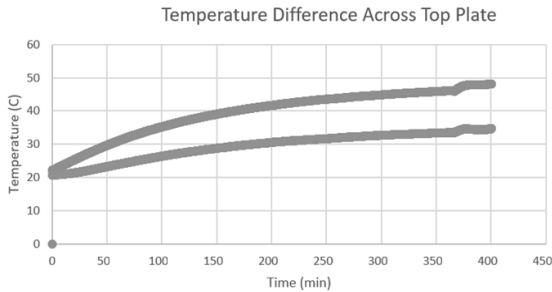


Figure 14. Temperature difference across the top plate of UHMW.

The third trial was conducted with a power input of 20 W, which was theorized to reduce the percent error of the thermal conductivity. Table 5 shows the results of this trial and that the reduction of power did not make a difference. This indicates that the thermal conductivity does not decrease significantly enough with temperature.

Table 5. Results from the third trial					
ΔT (°C)	Q (W)	$2A$ (m ²)	ΔX (m)	k (W/m.K)	Percent error
13.02	20	0.076	0.0127	0.256	35.9

Discussion

For this trial, the power input was reduced to 20 W to determine whether the thermal conductivity of the UHMW plastic was changing with temperature. The results show the percent error was still 35%. This suggests that the thermal conductivity of the UHMW did not change with temperature. It can also be seen that the trial did not fully reach steady state. This was because the apparatus had to be shut down. The apparatus was built at SUU and was required to be monitored by a student or faculty at all times. The test started at 5:30 AM and was terminated at 7:00 PM.

Trial 4 (GAF)

After getting a consistent 35% percent error throughout each experiment regardless of changing the test method, it was postulated that the UHMW sheets that were obtained did not actually have a thermal conductivity of 0.4 W/m.K. To obtain further insight and validation to the experiment that was performed the UHMW sheet was sent off to a

local company, GAF. GAF used the FOX 314 [12] thermal conductivity measuring device to determine the UHMW’s thermal conductivity. The company took 3 individual tests and sent back the average of the tests along with information on the machine they used. The thermal conductivity that GAF provided is shown in Table 6. This table also compares the worst error we observed (trial 1) with GAF’s result. In this case, the error is approximately 3.5%.

Table 6. Data from GAF compared to Trial 1		
GAF k (W/m.K)	Trial 1 k (W/m.K)	Percent Error
0.256	0.265	3.5

Error Analysis

Possible sources of error include machine calibration, operator bias, test method, and specimen fabrication. Each thermistor should be calibrated to match the temperature of the room. Each thermistor was not calibrated because we assumed that the change in temperature was the significant factor. This was later reconsidered as a variance of 1 degree could produce a percent error of up to 3%, and in future experiments, the thermistors will be calibrated to room temperature.

As Trial 3 had to be cut short, this could have resulted in some error; however, this is highly unlikely as the percent error was consistent.

The method is based on Fourier’s Law of heat conduction for steady-state one-dimensional. The box is not truly a one-dimensional plane wall. As a result, a small portion of error can be attributed to the test method. Each trial was only performed once because of time constraints. Each trial takes approximately one day to run. Following the trial, the data needed to be analyzed. The decision was made to make adjustments to the experiment following each trial rather than test for repeatability. However, it can be seen that even with the changes the percent error was still consistent.

Specimen fabrication is expected to play a significant role in the error shown. If the thermal conductivity of the material varies by 0.01, it can result in a percent error approximately 5%.

The thermal conductivity instrument utilized in Trial 4 has very limited uncertainty information available. Table 7 provides the uncertainty of thermal conductivity measurements [13]. It does not provide the full systematic and random uncertainty elements. It simply provides two elemental errors contributing to the systematic and random uncertainties. These two elemental errors are the accuracy (1%) and reproducibility/repeatability (0.5%). It is not specified whether these two values are for

the full range of the thermal conductivity or a single measurement. The worst scenario considers the full range of the thermal conductivity (0.005–0.35, W/m.K). In this range, the total uncertainty is evaluated as [14]:

$$B_k = \text{accuracy} * \text{full range} = \frac{1}{0.00345} (0.35 - 0.005) \frac{W}{m.K} =$$

$$P_k = \text{reproducibility} * \text{full range} = \frac{0.5}{100} (0.35 - 0.005) \frac{W}{m.K} =$$

$$0.001725 \frac{W}{m.K} \quad (3)$$

$$W_k = \sqrt{B_k^2 + P_k^2} = 0.003857 \frac{W}{m.K}$$

where B_k is the systematic uncertainty of thermal conductivity measurement (W/m.K), P_k is the random uncertainty (W/m.K), and W_k is the total uncertainty (W/m.K). As it can be seen from the analysis, the uncertainty of the thermal conductivity utilizing the FOX 314 instrument is very small and may be ignored.

Table 7. FOX 314 thermal conductivity instrument [13]

	 FOX 200	 FOX 314
Maximum Sample Thickness	51 mm (2 inch)	100 mm (4 inch)
Square Sample Width ⁽¹⁾	200 mm (8 inch)	300 mm (12 inch)
Temperature Range	-20 °C to 75 °C	-20 °C to 75 °C
Temperature Resolution	±0.01 °C	±0.01 °C
Accuracy	±1%	±1%
Reproducibility	±0.5%	±0.5%
Thermal Conductivity Range ⁽²⁾	0.005 to 0.35 W/m·K (0.035 to 2.4 BTU in/hr ft² °F)	0.005 to 0.35 W/m·K (0.035 to 2.4 BTU in/hr ft² °F)
Available Configurations	Automatic Sample Feeder External Thermocouple Kit Vacuum	Automatic Sample Feeder External Thermocouple Kit Linear Gradient Guard
Proprietary Thin Film Heat Flux Transducer	75 mm × 75 mm (3 in) Top and bottom	100 mm × 100 mm (4 in) Top and bottom

CONCLUSION

Although the test method changed from having UHMW on both sides of the apparatus in Trial 1 to having only one piece of UHMW at the top of the apparatus in Trial 2, to reducing the power input by half for Trial 3, all trials had very similar percent errors. This indicates that

the convection heat transfer did not change much as the test was performed vertically vs. horizontally. It also indicates no significant change in the thermal conductivity of the material with increasing temperatures.

The results from GAF indicate that the thermal conductivity of the test material may not have actually been 0.4 (W/m.K). Further experimentation on materials with certified thermal conductivity values may be performed to validate the accuracy of the test apparatus. It can be concluded that the material used in this experiment most likely does not have a thermal conductivity of 0.4 (W/m.K). Further experimentation should be performed to verify this hypothesis.

RECOMMENDATIONS

In the future, this experiment could be improved by making a few changes in the design of the heat transfer experiment. These adjustments include:

1. Reduce the surface area.
 - a. By reducing the surface area, the amount of volume inside the box for natural convection to occur will be reduced. This is expected to reduce the error from natural convection.
 - b. A smaller surface area will also theoretically result in a more uniform temperature distribution across the material.
2. Decrease the distance between the heat source and the material.
 - a. If this could be decreased to zero, this would eliminate convection on the inside entirely. The only concern would be localized heat. If this can be achieved, it is expected to minimize the error from convection inside the box.
3. Perform a detailed analysis and optimize the input power. When the input power is reduced, the temperature difference between the solid and ambient temperature is reduced. This will significantly reduce the amount of the parasitic heat loss.
4. Design a short cylindrical system. A cylindrical system would remove the corners from a square box. This would result in a more even distribution of temperature across the plate.

ACKNOWLEDGMENTS

The authors would like to thank Briana Mount for her contribution to this research. Her comments assisted us in writing this paper. Our sincere thanks also goes to the Engineering and Technology department at

SUU for their support. Without their precious support and facility, it would not be possible to conduct this research.

We would also like to thank the Utah NASA Space Grant Consortium for additional funding and support. Lastly, the authors would also like to thank Alexis Carter and Alauna Christensen for their patience and support throughout the duration of this research.

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Measuring the Thermal Conductivity of Air

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ABSTRACT

Thermal conductivity is a measurement of the ability of a material to conduct heat. It is easier to measure the thermal conductivity of solid materials. However, it is much more difficult to measure the thermal conductivity of gases. This is due to convection heat transfer in gases making up the majority of how heat is transferred. In the early 18th century, the thermal conductivity of air was thought to be too difficult to measure and nearly impossible to calculate. In 1872, Josef Stefan set out to build a device capable of measuring the thermal conductivity of ideal gases (including air). Around this era, there were attempts to measure the thermal properties of gases with minimal success. The problem was finding a way to change the temperature of ideal gases without causing natural convection currents. This issue was solved when Josef Stefan developed the diathermometer. The goal of this experiment is to build the Stefan diathermometer to measure the thermal conductivity of air. A following paper will discuss the experimental results and theoretical modeling.

INTRODUCTION

The diathermometer [1] comprises two concentric cylinders, arranged such that one is inside the other with a small gap between the two cylinders. The tested ideal gas (air in this case behaves as such) is contained in both cylinders. The small gap ensures natural convection currents will not occur and the heat transfer through the ideal gas is only by conduction heat transfer. If the gap is small enough, then natural convection currents may be ignored and heat transfer is entirely by conduction.

The design of the diathermometer utilizes the ideal gas law to measure the amount of heat transfer by measuring the pressure difference caused by a temperature change [2]. For this experiment, the room temperature diathermometer is submerged in an ice bath. The heat is then transferred from the inner cylinder, through the ideal gas, to the outer cylinder and to the ice bath. A consequence of the cooling during this process is that the pressure of the ideal gas inside the inner cylinder decreases. Using a manometer, the pressure is measured at small time intervals. In analysis, this pressure difference is then translated into the transient thermal conductivity. The process of constructing a diathermometer to measure the thermal conductivity of ideal gases is presented in the following sections.

BUILDING THE DIATHERMOMETER

Materials and Equipment

- 2 in $\times$ 12 in brass cylinder
- 1-7/8 in $\times$ 12 in brass cylinder
- 2 in copper flat end cap fitting
- 1-1/2 in copper flat end cap fitting
- 2 1/4 npt brass nipple fittings 1-1/2 in long
- 4 1/4 npt brass nipple fittings 2-1/2 in long
- 4 1/4 npt brass tee fittings
- 5 1/4 npt brass ball valves
- 2 1/4 npt non corrosive vacuum gauges 30 to 0 in. of Hg
- Loctite epoxy
- Silver solder
- Propane torch
- Ohaus Trooper scale
- General electric scale
- Machine shop

Assembly procedure

This experiment requires machining a custom diathermometer. The process of making the diathermometer started with using a 3D solid modeling program called Solidworks. With the rough dimensions from hand calculations and pictures of previous diathermometers [1], a 3D model was created. Figure 1 shows the 3D model of the diathermometer. McMaster Carr supplied all the parts used in construction except for the cylinders, which were purchased from a local plumbing supply store. McMaster Carr also supplied 3D CAD files of their parts online aiding with drafting of a 3D model.

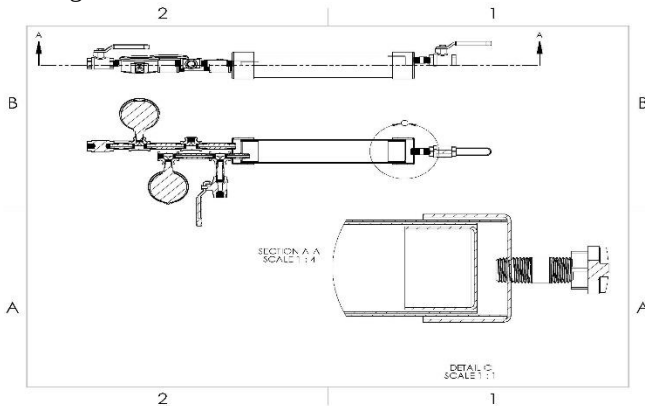


Figure 1. 3D solid model of the diathermometer.

The first step of assembling the diathermometer is to take the two brass cylinders to the machine shop to have the two cylinders faced and cut to the proper size. To have an object faced means to clean the faces by removing a small amount of material so it becomes flat. This process is either done on a lathe or a mill depending on the shape, size, and type of material. The 2-in diameter copper cylinder was measured at 11.766 in long. The inside copper cylinder was cut to 11.266 in long. The half-inch difference between the two cylinder lengths allows space for the pipe fittings. The pipe fittings are screwed in and sit 1/4 inch inside of the caps. If the gap between the cap and fittings is too small ($\sim 1/16$ in) then the air pressure, and subsequently the temperature, cannot be measured with the gauges used.

The next step is to have the holes in the end caps drilled. Figures 2 and 3 are detailed sketches for the holes drilled in the copper end caps. These holes are for the pipe fittings. It is important for these holes to be

as close to exact as possible as they are used to hold the inside and outside brass cylinders concentric to each other. Figure 4 shows the resulting drilled holes for the top copper end caps.

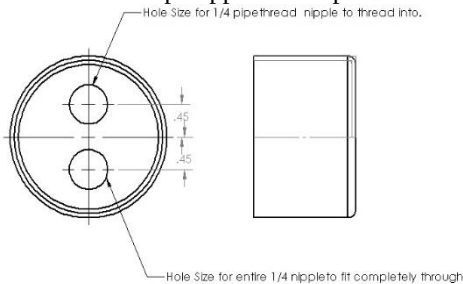


Figure 2. 3D model for 2-in copper cap with dimensions.

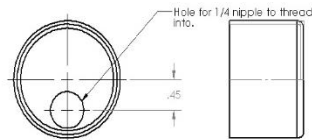


Figure 3. 3D model for 1-1/2 in copper cap with dimensions.

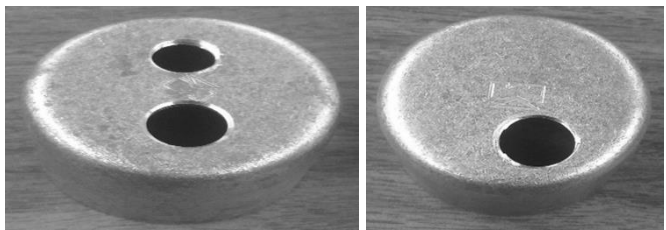


Figure 4. (Left) 2-in copper cap with holes drilled and tapped. (Right) 1 1/2-in copper cap with holes drilled and tapped.

For the purpose of the experimental calculations, the parts of the diathermometer were labeled using a permanent marker and their weight measured. Each part was weighed three times and the weights were averaged. The resulting weights are presented in Table 1.

Table 1. Weight of each individual parts				
Materials	Weight 1 (g)	Weight 2 (g)	Weight 3 (g)	Mean Weight (g)
2 " brass outside cylinder	340	340	340	340
1 7/8" brass inside cylinder	290	290	290	290
2" copper cap (2 holes)	129.947	129.942	129.942	129.944
2" copper cap (1 hole)	126.365	126.366	126.365	126.365
1 1/2" copper cap (1 hole)	71.271	71.269	71.268	71.269
1 1/2" -1/4 nipple				
1	19.887	19.887	19.887	19.887
2	19.837	19.836	19.836	19.836
3	20.064	20.062	20.063	20.063
4	20.009	20.009	20.009	20.009
5	19.895	19.894	19.894	19.894
1/4 brass T connection				
1	57.476	57.472	57.471	57.473
2	58.034	58.037	58.036	58.036
3	57.16	57.159	57.162	57.160
4	56.73	56.728	56.729	56.729
1/4 brass ball valve				
1	143.754	143.755	143.752	143.754
2	145.758	145.757	145.756	145.757
3	143.668	143.666	143.667	143.667
Oil filled vacuum gauge				
1	210	210	210	210
2	210	210	210	210

The next step in the assembly process is to glue the inside cylinder together. Rubber o-rings are used to insulate the cylinders and hold them in position. Using the rubber o-ring to hold the copper end caps and the 1 7/8-in brass pipe, slide the o-ring over the 1 1/2-in copper cap so the o-ring is at the very top edge of the end cap as seen in Figure 5. Gently slide the cap and o-ring inside the brass 1 7/8-in brass pipe as seen in Figure 5. A flat-head screwdriver may help guide the o-ring inside. Gently push the end cap so the copper end cap is flush with the end of the brass pipe. Once the cap is flush, use feeler gauges and confirm the cap is concentric with the brass pipe. Set the 1 7/8-in brass pipe and copper cap on end so the copper cap is upwards. Use the Loctite self-mixing

epoxy to fill the edge between the cap and pipe. To ensure an airtight seal, continue to add epoxy until it completely covers the entire copper end cap. Once this step is completed, add one of the spacer nuts next to one of the edges so it does not interfere with the air flow. Set aside to cure for 24 hours.

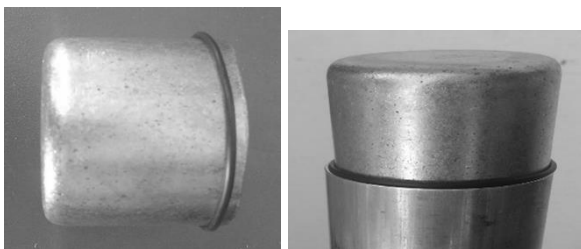


Figure 5. (Left) O-ring on 1 1/2-in cap. (Right) 1 1/2-in cap with o-ring partially inside the 1 7/8-in brass pipe.

To solder all the brass fittings to the appropriate copper end caps, start with the 1 1/2-in copper cap with one hole. Screw in the 1/4 npt by 1 1/2-in brass nipple fitting into the hole. Using a propane torch, get the cap and nipple fitting hot and solder them together using silver solder. Set the cap aside to cool.

Gather the two 2-inch copper end caps and two more 1/4 npt by 1 1/2-in brass nipple fittings. Screw the fittings into the end caps until the nipple fittings are finger tight. Do not use a tool to tighten these fittings as there is only one complete thread in the end caps. Too much torque will strip the threads making it difficult to create a good airtight seal. Solder the fittings together, and set aside to cool. Figure 6 shows the resulting fittings soldered together. Note that the 2-in copper end cap with two holes has not been soldered together in the picture. The fitting was soldered shortly after the picture was taken.

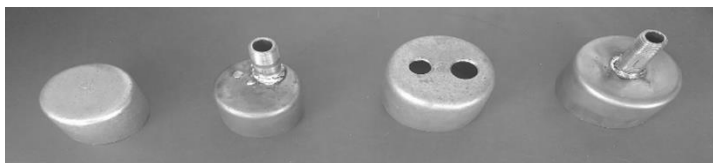


Figure 6. Soldered end caps.

After the fittings have cooled, the assembly process continued. The next step is to glue the 2-in copper cap with one hole to the 2-in brass

cylinder. Slip the o-ring over the end of the 2-in brass pipe so it is as close to the end as possible. Set the cylinder so the copper cap is at the bottom. Figure 7 shows the cylinder held vertical using another cylinder the same diameter as the copper end cap. Using the Loctite epoxy, fill the gap between the brass pipe and copper end cap until completely sealed. While applying the epoxy, gently pull and twist the brass pipe. This will allow the epoxy to settle deep into the gap continue to add epoxy so the gap is filled. Be sure to make the brass pipe and copper cap are concentric before the epoxy sets and becomes hard. Allow the pipe and end cap to cure for 24 hours.



Figure 7. (Left) Copper cap and brass pipe held vertical. (Right) 1 7/8-in pipe with 1 1/2-in copper end cap concentric and flush.

At this point, the 1 1/2-in copper cap and 1/4 npt by 1 1/2-in brass nipple fitting should be soldered together. Place the o-ring on the end of the 1 1/2-in copper end cap and press it inside the 1 7/8-in brass pipe so the top of the cap is flush with the end of the brass pipe as seen in Fig. 7. Use feeler gauges to ensure the cap and pipe are concentric. Fill the gap and entire top with the Loctite epoxy. Once the end is completely covered in epoxy, place the spacer nut onto the end of the cap before the epoxy sets and begins to harden. The inside cylinder is now complete. Set it aside to dry for 24 hours.

To pressure test the inner cylinder, add Teflon tape to the 1/4-in npt nipple fittings and vacuum gauge. Screw one of the 1/4-in npt tee fittings to the nipple on the inside cylinder and then the pressure gauge to the tee. Finish this pressure test assembly by screwing on the other nipple fitting to the last hole on the tee fitting and screw on one of the brass ball valves. Ensure all the fittings are tight for a good airtight seal. Apply a vacuum to the cylinder, and close the ball valve with the applied vacuum so there is a static applied vacuum pressure in the cylinder. Allow 30 minutes or longer to pass and check the pressure. If the pressure is at the

original recorded pressure, the inside cylinder is air tight. Remove the fittings and set aside.

After the inner and outer cylinders are completed and the bottom end cap has dried, the two cylinders can be assembled together. Slip the inner cylinder and outer cylinder together. Place the o-ring on the outer edge of the 2-in brass pipe and slip the 2-in copper cap over the end so the 1/4-in npt nipple fitting from the inner cylinder is protruding out of the larger hole of the 2-in copper cap as seen in Figure 8. Once the copper cap is in place, flip the cylinders upside down and fill the gap with the Loctite epoxy. The cap should hold the inner and outer cylinder concentric. Allow 24 hours for the epoxy to cure.



Figure 8. (Left) 2-in copper cap with 1/4-in npt nipple. (Right) Soldered 1/4-in npt nipple fittings on top 2-in end cap.

With the cap dry, add Teflon tape to the threads of the 1/4-in npt nipple fitting for the inside cylinder and screw on 1/4-in npt tee fitting labeled I. Ensure this fitting is tight and the perpendicular face on the tee is parallel to the outside of the cylinder. Screw in one of the 1/4-in npt 2 1/2-in long nipple fitting into the top 2-in copper cap. Solder the two 1/4-in npt nipple fittings to the top 2-in copper cap as seen in Figure 8. Once the cylinders have cooled, then pressure test the two cylinders.

The pressure test is done by adding Teflon tape to the threads of the 1/4-in npt nipple fittings on the cylinders, the pressure gauges and two more 1/4-in npt nipple fittings. Screw on a ball valve on the 1/4-in npt nipple fitting on the bottom of the two cylinders, and a tee fitting to the 1/4-in by 2 1/2-in long npt nipple fitting. Add a 1/4-in npt nipple to each of the top 1/4-in npt tee fittings, and screw on a ball valve to each of the nipple fittings. Add the vacuum pressure gauges to the other available holes on the top 1/4-in npt tee fittings. Apply a vacuum to each of the cylinders and seal them by closing the ball valves. Record the vacuum pressures, and set the apparatus aside for 30 minutes. Check the vacuum

pressure gauges to see whether the readings have changed. If there is no leak, continue with the assembly.

Add Teflon tape to all male-threaded brass fittings for assembly preparation. Screw on the 1/4-in npt tee fitting labeled II and tighten the tee fitting so the perpendicular face is parallel to the outside cylinder. Next screw on one of the other 1/4-in npt by 2 1/2-in long nipple fittings to the tee fitting labeled 2-in Roman numerals as seen in Figure 9. Add tee fitting labeled III to the 2 1/2-in nipple fitting that is attached to tee fitting number 1. Tighten the third tee so the perpendicular face is also parallel to the outside cylinder. Next, screw on one of the remaining 2 1/2-in nipple fittings to the tee fitting labeled II. Screw on the last tee fitting so the perpendicular face is also parallel to the outside cylinder edge. With the fittings all tightened, the resulting apparatus is presented in Figure 9.

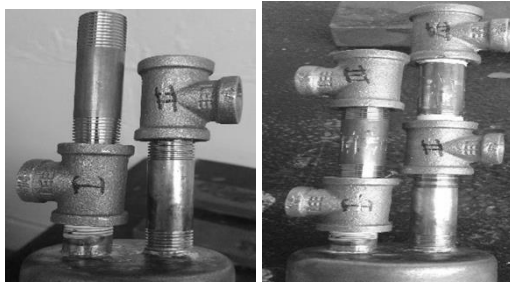


Figure 9. (Left) Tee fittings I and II with 2-1/2 nipple fitting. (Right) Brass fittings tight and aligned in correct orientation.

Next, the temperature probes must be prepared. Using the thermocouples with the blue polyurethane coating, slip the end of the thermocouple through the 1/4 npt $\times$ 1/8-in brass hose barb and pull enough of the wire through so the probe end will reach the center of the air cavities inside the cylinder. To measure the required length, place the 1/4 npt threaded end so it is aligned with the perpendicular end of either brass tee fittings I or II. Trace the path of the brass pipe with the wire of the thermocouple pulling enough wire through so the end is approximately the correct area of the desired cylinder. This is the approximate length of the thermocouples. To avoid the thermocouples touching the cylinder walls, use shrink tube to cover the tip. Repeat these steps for the other tee fitting. The thermocouple for the inside cylinder should be longer than the thermocouple for the outside cylinder. Using the Loctite epoxy fill the insides of the 1/4 npt $\times$ 1/8-in brass hose barbs to create an airtight

seal and to hold the thermocouples at the correct desired length. Set these aside to dry for 24 hours.

The last of the assembly is completed by added the vacuum gauges, temperature probes, and ball valves. This is done by adding Teflon tape to both 1/4-in npt by 2-1/2 long and 1-1/2 nipple fittings. Screw on the 1-1/2-in nipple fitting to the brass vertical end of the tee fitting labeled 3 in roman numerals and add on a ball valve to the other end nipple fitting. Complete the same process with the 1/4-in npt by 2-1/2 long nipple to the tee fitting labeled number 4.

Next, add the vacuum gauges to the horizontal holes on the tee fittings labeled 3 and 4 such that both the gauges are capable of being read at the same time without adjusting the apparatus. Add the thermocouples to the already predetermined tee fittings. The resulting apparatus is shown in Figure 10. Perform another vacuum test on the completed diathermometer apparatus to ensure there are no leaks in the system.

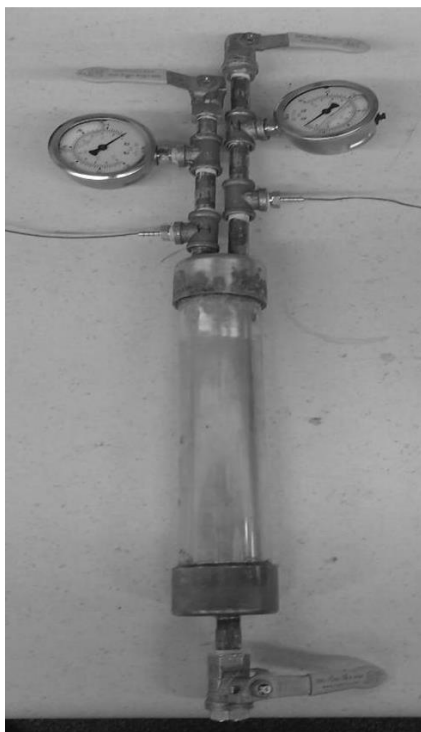


Figure 10. Completed diathermometer.

RUNNING THE EXPERIMENT

Materials

- Student-built diathermometer
- Manometer
- Visual recording device (student camera phone)
- Digital thermometer logger
- 3 thermocouples
- Ice water and 90-qt cooler
- 1/4-in diameter $\times$ 6-feet-long clear rubber hose
- Brick (or other insulative material)

Test Procedure

For this experiment, the thermal conductivity of air is measured. Air at standard temperature and pressure (STP) is considered an ideal gas. The tested air starts at room temperature and at 0 mm of H₂O gauge pressure. The following procedure shows the steps to complete the testing.

1. Open the 2 top ball valves on the diathermometer ~10 minutes before testing to ensure that the air inside the cylinders is at room temperature and to eliminate any pressure differences between the cylinders and the ambient atmospheric pressure.
2. Connect the thermocouples to a digital thermometer logger.
3. While the diathermometer is reaching the steady state, place the cooler on a stable surface ~6 feet off the ground. This allows the water in the manometer to move up the tubes when the vacuum is applied without the water entering the cylinder of the diathermometer. Add 30 lbs of ice to the 90-qt cooler. Add water to the cooler so the ice water solution fills half of the cooler.
4. Gently place the brick in the slot so it rests between the walls of the cooler and the ledge at the halfway point in the cooler. The brick is used to hold the gauges and ball valves out of the ice bath without transferring any energy from the ice bath to the gauges.
5. Connect the 6.5-foot-long clear 1/4-in hose to one of the hose barbs on the bottom the TQ manometer. Use a hose clamp on the connection to eliminate leaks. Place the manometer close to the cooler such that the 6.5-foot long hose is almost vertical.

6. Remove the top cap from the pressure cylinder on the manometer that is connected to the 6.5-foot long hose so the system is open to atmospheric pressure.
7. Add water to the clear hose until the water level in manometer reads 600 mm of H_2O . This water height allows enough travel for the water when the vacuum is applied without water entering the diathermometer. Remove any bubbles in the water lines. Note that the water level does not have to be exact as long as the height difference is recorded accurately.
8. Connect the other end of the clear hose to the hose barb on the diathermometer. Use a hose clamp and tighten the connection to ensure no air leaks. This will read the pressure change for the inner cylinder. Keep the diathermometer higher than the water level in the 6.5-foot-long hose. If water enters the inner cylinder, the diathermometer will have to dry for 24 hours to ensure no liquid is present.
9. Stir the ice bath to ensure the temperature of the ice bath is consistent throughout the cooler. Measure the ice bath temperature; it should be around 0°C .
10. Set up the visual recording device so the water level in the manometer can be read and press record.
11. Lift the diathermometer up to the level of the ice bath. **DO NOT PLACE INTO ICE BATH YET.**
12. Close all the ball valves.
13. Announce the start of the test so it can be heard by the visual recording device.
14. Submerge the cylinders in the ice bath as seen in Figure 11. Gently close the lid of the cooler without crushing the clear hose attached to the manometer.
15. The visual recording device and digital thermometer logger will record the pressure and temperature changes.
16. The diathermometer needs to remain in the ice bath for approximately 10 minutes to reach 0°C . After 10 minutes, the diathermometer will have reached thermal equilibrium with the ice bath.
17. When the pressure reading is stable (not changing), stop the recording on the visual recording device and the digital thermometer logger.
18. Pull the diathermometer out of the ice bath and open the ball valves releasing the pressure.
19. At a later date, repeat the testing protocol for another 3 tests. The different day has different atmospheric pressure. Having multiple tests on different days removes biased results.



Figure 16. Diathermometer placed in ice bath.

RECOMMENDATIONS

Throughout this experiment, difficulties were encountered that affected the accuracy of the ending results. The recommendations section has been broken up into subsections for clarity.

Construction

During the building process, a few different approaches were used to assemble to diathermometer. The biggest change was using copper end caps because of the short time schedule and the cost to order more materials. For the next assembly, it is suggested to order a piece of 2-in brass round stock ~6 in long. The cost of purchasing this piece is roughly \$100. This piece can be machined down to the proper diameter and thickness. The increased thickness allows the brass fittings to be threaded deeper into the ends of the cylinders. This creates a better seal and a sturdier design, and the precision from machining the parts makes it easier to make the cylinders concentric. Another reason to use the 2-in brass round is the ability to solder the ends to the brass pipe. Using solder creates a better seal, allows higher pressure tolerance, and is not affected by temperature changes like the Loctite epoxy.

Another change to the design of the diathermometer is an addition of another ball valve to the bottom accessing the inside cylinder. With this addition, the ideal gas for the inside cylinder can be easily replaced. Unfortunately, this adds another area to diagnose for a possible leak. Be sure to properly solder everything together and pressure test the inside cylinder system before final assembly.

When the testing started, it was realized that the pressure gauges were not accurate enough for the experiment. The gauge for the inside cylinder was replaced with a hose barb. The hose barb was connected to the TQ manometer. This allowed for more accurate results. A recommendation would be to utilize a digital manometer sensitive enough to measure the vacuum pressure of approximately -0.8 psig.

During the testing, the temperature was measured for both cylinders. The temperature was measured using one thermocouple for each cylinder. It would increase the accuracy of the experiment to measure the temperatures of the cylinders with multiple thermocouples. This could be done by replacing the 1/4 npt $\times$ 1/8 hose barbs. There is a 1/2-in rubber compression fitting that has multiple holes for wires. Using a 1/2 compression to 1/4 npt adapter, the fitting could replace the hose barb and allow multiple thermocouples.

Testing

During the testing phase, multiple issues arose. One of the biggest issues was the pressure measurements. The pressure was measured using a manometer, which provided great results, but it was difficult to measure the pressure with time. This was done with a visual recording device, played back second by second on a computer, and manually entered in Microsoft Excel. This was very time consuming. A good testing recommendation is to find a way to accurately measure pressure with time and have it record the information in a table. Using a digital manometer with a data logger would eliminate this problem.

Another recommendation is to have multiple ways to measure both the ambient air temperature and the ice bath. The thermocouples needed to be more accurately calibrated. Occasionally, the thermocouple measuring the ambient air and ice bath was not accurate. It measured the ice bath to be a negative temperature.

During the testing, the temperature differences in the cylinders, the ice bath temperature, and the ambient air temperature were measured. The measured temperatures should be measured multiple ways to avoid bias. A suggestion is to add multiple thermocouples to the system. The thermocouples that are added to the cylinders can be averaged. This would decrease the bias.

ACKNOWLEDGMENTS

This project would not have been possible without the support of SUU. The Department of Engineering and Technology provided financial support for some key pieces of equipment and technical expertise from the professors and instructors in the department. We would also like to thank the Utah NASA Space Grant Consortium for additional funding and support.

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Creating a Phase Change Thermal Energy Measurement System (Part 1: Design and Construction)

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ABSTRACT

In the last 40 years, interest has grown significantly in the utilization of passive thermal energy stored or released during the phase change of a substance. A variety of applications exist for the use of latent heat energy such as building heating, ventilation, and air conditioning systems, electronics cooling, and passive heating and cooling of instruments in space. Studies have been conducted in this field, but there are still many possibilities for undergraduate engineering research to lead to new advancements in the field of phase change heat transfer. The objective of this project was to design and construct a test-system to be utilized for undergraduate experimentation and research in the thermal behavior of the solid-liquid phase change materials. The system consisted of a vertical copper test cylinder (vessel) that was heated and cooled inwardly by using copper tubing wrapped in a counterflow arrangement around the outside of the test vessel. The copper tubing is connected to a constant temperature bath (CTB) that can provide fluid to heat or cool the copper vessel in the range of -20°C to 100°C . The progress of the phase change

was monitored using an array of more than 100 thermocouples. Currently, water is being utilized as the phase change material to validate the test system. Future work will consist of testing 99% pure eicosane ($C_{20}H_{42}$), investigating the use of porous copper foam in conjunction with eicosane to improve heat transfer performance, and measurement of the thermal conductivity of the porous media saturated with the phase change material. Future users of the test system will be able to gain a better understanding of how this phase change energy is stored and released in different materials and applications.

INTRODUCTION

Materials exist in one of three phases: solid, liquid, or gas. These phases are characterized by the amount of energy stored in the material. Heating or cooling a material adds or removes energy, respectively, from the substance. A material's phase change involves a greater amount of energy at the fusion temperature than it is heated or cooled while not changing phase. It is worth noting that while a material is absorbing or losing energy during a phase change, ideally, it will remain at a constant temperature and the energy released or gained is called the heat of fusion.

As concerns about efficient energy use grow, so has interest in taking advantage of the passive thermal energy absorbed or released when a material changes phase. Examples have been seen in the study of the formation of Earth's crust, medical cooling of organs, and satellite passive heat storage units for NASA. A survey of the experimental literature [1-8] reveals some effort focused on the melting or freezing of a phase change material (PCM) in externally heated or cooled cylinders.

Phase change thermal storage and control devices have been discussed extensively in the literature over the years. Several of these articles refer to a device that either thermally controls or stores energy by using a PCM. There are three types of phase change transformations that can be studied: solid-liquid, liquid-gas, and solid-gas. Since liquid-gas and solid-gas transformations are impractical to study for undergraduate research because of the complexity of analysis and needed equipment, they will not be addressed. However, the solid-liquid phase transformation presents an interesting research opportunity that is within the grasp of undergraduate researchers.

The objective of this project was to design, build, and troubleshoot a test system for detecting one-dimensional radially inward heat transfer of a PCM. The system was validated using deionized water as the PCM.

TEST VESSEL SYSTEM

The test vessel system consists of an 18-inch-long, 6-inch-nominal diameter vertically oriented copper vessel. The copper vessel is wrapped by two 5/8-inch nominal diameter copper tubes in a helical pattern allowing for approximately ¼-inch space between each wrap. The two copper tubes are set up in a counterflow configuration, and polydimethylsiloxane (PDMS), as a heat transfer fluid, is supplied by the constant temperature bath (CTB). The counterflow arrangement of the copper tubing allows for more consistent and uniform heat transfer across the test vessel than a single-direction flow configuration. Figure 1 shows the arrangement of the copper tubes on the vessel.



Figure 1: Copper vessel with copper tubing wrapped in a helical arrangement.

Copper, which has a thermal conductivity of $401 \text{ W}/(\text{m}\cdot\text{K})$ [9], was chosen for the tube and vessel to maximize the heat transfer from the PDMS (the working fluid) to the PCM. The ends of the copper test vessel are sealed with acrylic caps that are fastened to the vessel by polyethylene terephthalate glycol (PETG) flanges. The PDMS is supplied to the copper counterflow heat exchanger through PEX (cross-linked polyethylene) piping feed lines. Acrylic, PETG, and PEX, which have thermal conductivities of $0.187\text{--}0.216 \text{ W}/(\text{m}\cdot\text{K})$, $0.190\text{--}0.225 \text{ W}/(\text{m}\cdot\text{K})$, and $0.41 \text{ W}/(\text{m}\cdot\text{K})$, respectively [10–12], were chosen to minimize the parasitic heat transfer. Figure 2 shows the uninsulated test vessel system without the data acquisition system.

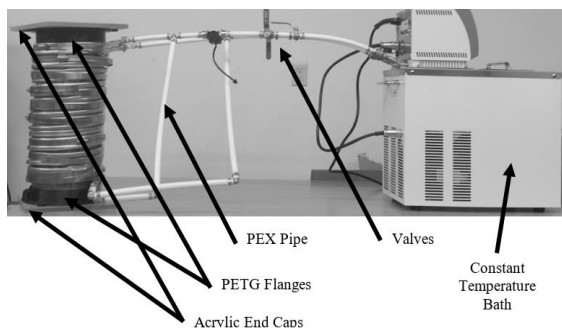


Figure 2: Uninsulated test vessel system without data acquisition components.

The temperature of the PDMS will be monitored at the inlet and outlet of the copper tubing. Thermocouples at regular intervals will also be inserted into the copper vessel to measure the progress of the inward solidification front of the PCM. The thermocouples are suspended in the PCM by way of the thermocouple tree. One side of each branch holds nine thermocouples per row, evenly spaced, and one on the tip of the branch. The opposite side of each branch holds a single thermocouple for reference. The reference thermocouple is compared with the thermocouple on the opposite branch that is at the same radial and vertical distances from the center of the tree. The reference thermocouples are placed at different points on each branch, allowing for comparison of the phase change at different radial distances and to demonstrate the viability of the assumption that the behavior of the PCM is the same on any plane at a specified radial distance (uniform heat transfer in the circumferential, θ , direction.). The top of the thermocouple tree, where the thermocouple wires enter the test vessel, will also act as the pressure and overflow vent for the system. This configuration provides a constant pressure process for the system. The vent portion of the tree extends above the acrylic test vessel lid and has a reservoir to compensate for the PCM expansion and contraction. The thermocouple ADC boards are mounted above the reservoir.

DESIGN AND CONSTRUCTION

In this section, detailed information on the design and construction of the test vessel system is presented.

Copper Vessel

Purpose: The 18-inch-long, 6-inch-nominal diameter copper vessel serves as the heat transfer medium and container for the PCM.

Acquisition: The decision to use an 18-inch-long by 6-inch-diameter copper vessel came largely from reviewing earlier work by Siahpush et al. [2], who originally used a 12-inch-long by 6-inch-diameter copper pipe for the test vessel. Based on this experience with end effects on the PCM, the authors recommended using a longer copper vessel. Copper has a high thermal conductivity and makes an excellent heat transfer medium.

Acquiring 18 inches of 6-inch-diameter type L copper pipe took more time than originally anticipated. It is not a commonly used size, and none of the pipe manufacturers or suppliers contacted were willing to cut a full-length pipe. Eventually, a company that sells 6-inch-diameter copper pipe by the inch was found. Details on the acquisition and cost of copper pipe can be found in the appendix.

Copper Tubing

Purpose: The nominal 5/8-inch copper tubing serves as a transport corridor for the heat transfer fluid supplied by the CTB and allows for heat to be transferred between the fluid and the copper vessel and by extension the PCM.

Acquisition: The amount of copper tubing needed was estimated by dividing the length of the copper vessel by 5/8 inch and multiplying the result by the circumference of the copper vessel. The 5/8-inch copper tubing was widely available and easy to acquire.

Integration: After consulting with Roger Greener, Instructional Staff at SUU [13], it was decided to press the tubing against the outside of the vessel using a CNC lathe running at low speeds. Note that although Siahpush et al. [2] soldered the tubing to the vessel, it was not feasible to do for this test vessel given the higher density of wraps. Wrapping the tubing with the lathe running proved unsuccessful, so the lathe was turned manually while the copper tube was fed onto the vessel. The pressed tubing was secured to the vessel using 7-inch-diameter steel hose clamps at regular intervals. Figure 3 shows the lathe setup.

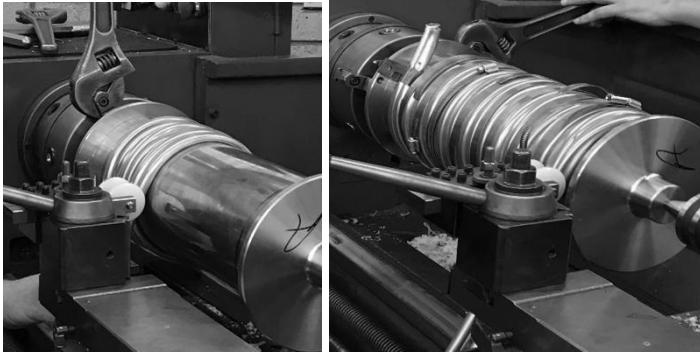


Figure 3. (Left) Wrapping counter-flow tubes on lathe. (Right) Wrapped vessel with hose clamps.

To secure the copper vessel in the lathe, it was necessary to design specialized construction end caps for the vessel and a clamp for the tubing. Although it was intended for the clamps to help flatten the copper tube, the clamps ended up being too small. Because of time and material restraints, it was decided to improvise with the clamps. Figure 4 shows one of the stainless steel end caps used to secure the copper vessel in the lathe.



Figure 4. Specialized construction end cap.

Lessons Learned: As previously mentioned, the clamp proved to be too tight for the 5/8-inch tubing. The opening made by the two clamps was designed to bend the tubing straight so it could be pressed against the body of the vessel. A larger clamp opening would be required to make this method effective.

End Caps

Purpose: The purpose of the end caps is to provide watertight closures on both ends of the copper vessel that have relatively low thermal conductivities.

Acquisition: The end caps for the final test vessel assembly consist of an acrylic top and a PETG flange. Both the 1/2-inch acrylic sheet and the PETG 3D printer filament are widely available (Table 1).

Fabrication: The end caps for the final test vessel assembly, as shown in Fig. 5, consist of an acrylic top and a PETG flange. The acrylic top was cut from a 1/2-inch acrylic sheet. The PETG flange was 3D printed. The flanges are sealed to the copper vessel using high-temp RTV silicone gasket. The bottom end cap is sealed to the flange using high-temp RTV silicone gasket, and a cork-rubber gasket seals the top end cap and flange. Both have 4 bolts securing the end cap to the flange. The difference in attachment between the end caps and flanges is to allow access the inside of the test vessel from the top orifice.

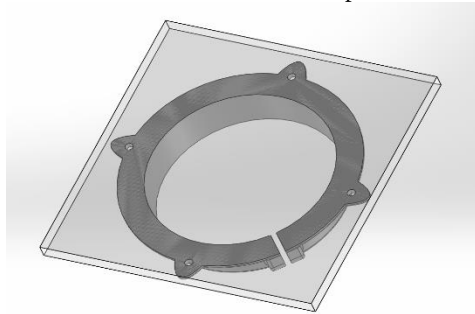


Figure 5. End cap assembly.

Constant Temperature Bath (CTB)

Purpose: The CTB allows a fluid to be heated or cooled and then maintained at a set temperature. A pump in the CTB circulates the fluid through any attached tubing or plumbing system. An ANOVA A25 CTB was selected to supply the counterflow heat exchanger connected to the copper vessel with a controlled temperature fluid. This allows a constant temperature thermal boundary condition.

Acquisition: After researching many online suppliers and requesting quotes from different companies, it was decided to order a CTB from Accurate Thermal Systems. The company had three models to choose from: Model R-10, Model A-25, and Model A-40. For the purposes of the project, it was important to acquire a bath with the following features:

1. A bath volume that could hold enough controlled temperature fluid, the PDMS, to adequately supply the system,
2. A temperature range that could freeze and melt water and other PCMs,
3. Enough power to maintain the temperature of the PDMS,
4. A pump that maintains a sufficient flow rate,
5. An integrated controller to run the CTB, and
6. A reasonable cost that fits into the budget supplied by Southern Utah University's Engineering and Technology Department.

After all these factors had been considered, the A-25 model was determined to be the best candidate.

CTB Fluid

Purpose: PDMS serves as the heat transfer fluid to provide adequate (hot or cold) temperatures to the test vessel system. This fluid is contained in the CTB reservoir.

Acquisition: Accurate Thermal Systems recommended two fluids for the CTB: low-temperature bath fluid (-20°C to 100°C) and ultra-low-temperature bath fluid (-40°C to 65°C). Low-temperature bath fluid (PDMS) was chosen because the range was more desirable for any foreseeable projects and allows for the freezing and melting of water while not voiding the warranty of the CTB.

Lessons Learned: Since the fluid is silicone-based, proper disposal methods must be observed. If disposal of the PDMS is required, local regulations and disposal procedures need to be considered. Evaporation of PDMS will occur over long periods of time, so the fluid level in the CTB should be checked before use.

The PDMS fluid was observed to compromise PTFE thread seal tape and pipe thread sealant ("pipe dope"), which led to some of the connections being soldered that otherwise would have been sealed with PTFE thread seal tape.

PEX Tubing

Purpose: PEX piping was chosen for its relatively low heat conduction properties and ease of use. PEX is used to connect the counterflow heat exchanger to the CTB.

Acquisition: PEX is a common material that can be found at most plumbing and hardware stores (Table 1).

Bypass Loop

Purpose: A bypass loop was incorporated into the fluid system that connects the CTB to the test vessel. The bypass loop allows the heating

or cooling of the PDMS heat transfer fluid without allowing it to circulate around the test vessel. Isolating the CTB while the heat transfer fluid is being brought to the desired temperature lessens the amount of time the heat transfer fluid is in a transient state during testing.

Fabrication: The bypass loop is located near the CTB outlet and inlet connections. This loop is equipped with three ball valves. One valve is located on the outlet piping, another is located on the inlet piping, and the third is located on a tube that connects the outlet and inlet (the bypass loop) (Fig. 6).

When the outlet and inlet valves are open and the bypass loop valve is closed, the system will allow flow into the counterflow heat exchanger around the test vessel. When the flow-through valves are closed and the bypass valve is open, the fluid will circulate from the CTB back into the reservoir. The loop allows the heat transfer fluid to reach the desired temperature before entering the test vessel heat exchanger.



Figure 6. Bypass loop with three ball valves.

Thermocouples

Purpose: Thermocouples function on the Seebeck effect, where a voltage is induced in an electrical conductor because of a temperature difference. The voltage is dependent on the type of conductor used, and thermocouple measurement is based on the difference between the voltage across two dissimilar conductors. Thermocouples provide fast and accurate temperature data.

Acquisition: Type K thermocouples were chosen for the temperature measurements, due to temperature range and availability. Perfluoroalkoxy alkane (PFA)-insulated type K thermocouple wire was used to make the sensors.

Fabrication: The thermocouple wire was cut to length, and the probe end spot welded to form the sensors. The thermocouples were

welded with a spot welder by a method developed through inspection of commercial thermocouple welders.

The thermocouples are attached to the thermocouple tree in the test vessel using a specialized epoxy for thermocouples.

Microcontrollers and Data Acquisition Program

Purpose: Purchasing a complete data acquisition system, such as LabView, was not within the budget. Therefore, a cost-effective approach was taken to learn more about electronics and data acquisition system. A large number of thermocouples needed for sufficient data acquisition requires an analog to digital conversion (ADC) system that can accommodate them. Thermocouples require the signals to be amplified to a usable level, and very few ADC systems can amplify and record information from so many thermocouples.

Acquisition: The LTC2984 Multi-Sensor High Accuracy Digital Temperature Measurement System with EEPROM [14] was chosen because of the presence of 20 input channels and the availability of open source software. The LTC2984 passes information for collection through an Arduino style microcontroller. Linduinos (Linear Technology's specially made Arduino) were chosen as the microcontroller because they were specifically constructed for use with Linear Technology devices. The special 14-pin "QuikEval" connector [14] allows the Linduino to communicate with the DC2420A demo board. The DC2420A demo boards integrate the LTC2984 ADC chip with a set of terminals connected to the ADC channels.

Integration: Data acquisition is carried out through serial data transfer from the LTC2984 to the microcontroller. The microcontrollers will then store the data on the testing computer. The LTC2984 demonstration software provided by Linear Technology is used for data acquisition, cold-junction compensation, and conversion of data for storage.

Circuit Board Design

Purpose: Originally, custom boards were designed to accommodate the LTC2984 chip. The custom boards were designed to utilize all 20 channels of the LTC2984 chip and to power and connect the chip to the microcontroller.

Acquisition: The LTC2984 circuit board was designed using Autodesk's Eagle PCB design software. The circuit was designed following the LTC2984 datasheet and was adapted from the schematics for the pre-made demo boards.

Fabrication: OSH Park was chosen to manufacture the PCBs and a stencil for reflow soldering of the LTC2984 chip. Figure 7 shows the two layers (front (left) and back (right)) of the designed PCBs.

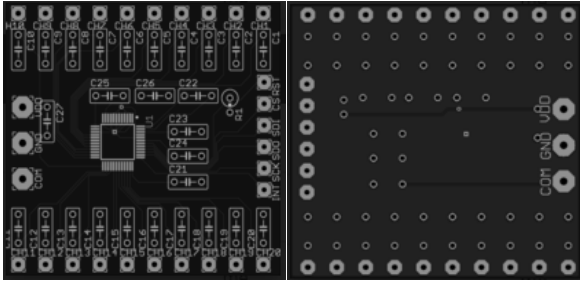


Figure 7. Front (left) and back (right) of LTC2984 connection circuit board.

Lessons Learned: The custom-designed boards were built and tested. The constructed boards functioned as expected. To facilitate the transfer of the research to future researchers, the pre-built DC2420A demo boards produced by Linear Technology [15] were used in the system. The availability of documentation and support, along with the ease of use with the premade software, were the major determining factors in the decision.

Temperature Acquisition System

Purpose: The DC2420A data acquisition system amplifies and converts the analog signals from the thermocouples to digital signals that are transferred through the microcontroller to the data acquisition software.

Acquisition: The DC2420A Evaluation Board [15] consists of the DC2399A main demo circuit with the LTC2984 chip and the DC2210 20-input breakout board. Other breakout boards that connect to the DC2399A main board are available that are designed to read specific types of temperature sensors, but the DC2210 has 20 inputs that allow any type of temperature sensor to be attached.

Integration: Six DC2420A demo boards are used in the system. In Figure 8, the thermocouple wires can be seen exiting the pressure relief opening in the overflow reservoir, and the wires connect to the DC2420A system. The 14-pin “QuikEval” connector on the DC2420A boards and Linduinos are used to link the ADC system to the data recording software. Thermocouples are connected to the 20-input breakout boards, with channel 1 reserved for cold-junction compensation sensors. 2n3906 transistors are used for the cold-junction compensation sensors. The transistors are connected in a diode configuration with the emitter connected

to channel 1, and the base and collector connected to the common ground. The LTC2984 uses the cold-junction diode temperature as a reference to adjust the thermocouple temperature output for ambient conditions.



Figure 8. Temperature acquisition system.

Thermocouple Tree Design

Fabrication: The thermocouple tree is 3D printed out of high-temperature polylactic acid (HTPLA) thermoplastic. HTPLA was chosen for the ability to heat treat the plastic, thus raising the glass transition temperature above the temperature range of the CTB. The tree is suspended from the overflow reservoir and pressure vent. The thermocouple wires exit the vessel through the pressure vent. Figure 9 shows the thermocouple tree during assembly. The thermocouples are attached following the configuration shown in Figure 9 using a thermally conductive epoxy. The ends of the thermocouples are left exposed to the PCM in the test vessel.



Figure 9. Thermocouple tree with thermocouples during assembly.

Integration: The thermocouple tree holds the thermocouples in place within the test vessel. The sensor configuration chosen places ten thermocouples on one side of the tree and one reference thermocouple on the other. The reference thermocouples are distributed so a reference point is present for each radial position of the main sensor array. The reference sensor provides validation of the assumption that the system can be modeled as a one-dimensional heat transfer system. The thermocouple tree is designed to be removable from the test vessel for maintenance.

CONCLUSION

At SUU, experiential learning is highly regarded as a means to teach a course. There is a proverb from Lakota Sioux that states “Tell me, and I will forget. Show me, and I will remember. Involve me, and I will understand.”

The objective of this project was to design and construct a test system to be used for an undergraduate experimentation and research in the thermal behavior of the solid-liquid PCMs. The system consisted of a vertical copper test cylinder that was heated and cooled inwardly by using copper tubing wrapped in a counterflow arrangement around the outside of the test vessel. The copper tubing was connected to a CTB that provided fluid to heat or cool the copper vessel in the range of -20°C to 100°C . The progress of the phase change was monitored using an array of >100 thermocouples. Currently, water is being used as the PCM to validate the test system. In part 2 of this research, heat transfer analysis of water freezing will be performed. Future work will consist of testing 99% pure eicosane ($\text{C}_{20}\text{H}_{42}$), investigating the use of porous copper foam in conjunction with eicosane to improve heat transfer performance, and measuring the thermal conductivity of the porous media saturated with the phase change material. Future users of the test system will be able to gain a better understanding of how this phase change energy is stored and released in different materials and applications.

This heat transfer project provided insight into the conduction, convection, and solidification heat transfer, and as one of the students involved in this project stated, “This project was heat transfer in action.” In addition to gaining a greater practical understanding of heat transfer concepts, the researchers gained valuable experience in designing and utilizing data collection systems. The total cost of components was approximately \$8000, and the time three students spent were approximately 1200 hours over a one-year period. It also should be mentioned that the Mechanical Engineering faculty spent over 300 hours to teach

students the fundamental of melting and solidification, guide the experiment, validate the experimental and analytical results, and review the report.

For a semester of a heat transfer experience, it is highly recommended to simplify the experiment and use only de-ionized water and avoid solidification. In this manner, only convection and conduction heat transfer are considered. Also, if the experiment is performed close to the room temperature, the parasitic (wasted) heat is minimized and more accurate results are obtained.

ACKNOWLEDGMENTS

This project would not have been possible without the support of the Walter Maxwell Gibson (WMG) College of Science and Engineering. The WMG Fellowship provided financial support for the researchers and money for material. The Department of Engineering and Technology provided financial support for some key pieces of equipment and technical expertise from the professors and instructors in the department.

We would also like to thank the Utah NASA Space Grant Consortium for additional funding and support. Barbara Rodriguez and Jamie Campbell were integral in helping us to navigate the purchasing equipment and supplies. Extra thanks should go to Barbara for helping us to navigate the WMG Fellowship Application process.

Lastly, we would like to thank our friends and family for their understanding and support through the many long hours spent on this project.

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APPENDIX: MATERIALS AND EQUIPMENT LIST

In this section, a detailed list of required material and equipment used in constructing the test vessel are presented in Table 1.

Table 1. Materials and equipment list				
Item	Amount	Brand and Model/Type	Acquired From	Cost (\$)
6" diam. copper pipe (vessel)	18"	Type L	moonshine-still.co	207
5/8" diam. copper tube	100 ft	ACR Refrigeration	Amazon	154
1/2" diam. PEX pipe	10 ft	Apollo 1/2 inch	PPS	9.75
1/2" ball valves	3	Mueller ProLine 107-343 NL	PPS	8.00/each
1/2" acrylic sheet	12×24"		Amazon	26.48
Spot welder	1	Tooluxe 1095L	Amazon	150.70
Type K thermocouple wire	500 ft	Omega Engineering GG-K-24-SLE-500	omega.com	215
PFA coated type K thermocouple wire	500 ft	Omega Engineering TT-K-24-500	omega.com	245
Constant temperature bath	1	ANOVA ATS3091 Model A25	Accurate Thermal Systems	2500
Constant temperature bath fluid	5 gal	ATS1049 Low-Temperature Bath Fluid	Accurate Thermal Systems	705

Table 1. continued				
Item	Amount	Brand and Model/Type	Acquired From	Cost (\$)
PEX crimp tool	1	IWISS FBA_Iwi-5581	Amazon	32.66
PEX pipe cutter	1	IWISS PPR	Amazon	8.85
High-temp RTV silicone gasket	3 oz	Permatex 81160	Amazon	4.72
1/2" brass PEX Ts	4		PPS	5.00/each
1/2" brass PEX 90s	6		PPS	1.00/each
50 pack of 1/2" stainless steel clamps	1	Oetiker 62318	Amazon	13.06
3/4×1/4" reducing coupling	2		PPS	7.00/each
1/4" brass pipe nipple	2		PPS	4.00/each
1/2×3/4" PEX × FNPT adaptor	2		PPS	5.00/each
1/2×3/4" PEX × MNPT adaptor	2		PPS	5.00/each
1/2" copper PEX sweat adaptor	4		PPS	1.50/each
Regular paste flux	8 oz	RectorSeal	PPS	11
Solder	1 lb	LucasMilhaupt SILVABRITE 100	PPS	35

Table 1. continued				
Item	Amount	Brand and Model/Type	Acquired From	Cost (\$)
7 1/8–10" hose clamps	4 packs of 5	5415k43	McMaster Carr	9.27/ pack
0.1 μ F capacitors	200	Jameco 544921	Jameco	0.15/ each
1 μ F capacitors	10	Jameco 27001	Jameco	0.59/ each
10 μ F capacitors	35	Jameco 52393	Jameco	0.35/ each
LTC2984 demo board	6	Linear Technology DC2420A	Linear Technology	125/ each
Multi-sensor high accuracy temperature measurement system	12	Linear Technology LTC2984CLX	Linear Technology	30.61/ each
Linduino	7	Linear Technology DC2026C	Linear Technology	75/ each
Circuit boards	12	N/A	OSH Park	19.15/ batch of 3
Solder stencil	1	N/A	OSH Stencils	7.75
Total				5729.06

Airglow Measurements from the SABER/TIMED Satellite

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Abstract

Mesospheric hydroxyl, molecular oxygen, and ozone airglow emission data from the SABER instrument on the NASA TIMED satellite are analyzed. Particular attention is paid to the dynamics of the altitude airglow volume emission rate (VER) profiles with the goal of establishing the cause or causes of occasional observed multi-peak and bifurcation anomalies in the tangent point limb emissions and in the derived VER profiles. These anomalies are important because they may lead to discrepancies in the analysis of the VER profiles. Knowledge about the causes and characteristics of the mesospheric airglow are important to understanding of the Earth's dynamic environment including climate change.

The SABER Instrument

The SABER instrument is a multichannel radiometer onboard the NASA GSFC/JHU TIMED spacecraft, which launched in December 2001 and became fully operational in January 2002. SABER is used to globally measure infrared emissions from the mesospheric/thermospheric regions of the Earth's upper atmosphere as illustrated in Figure 1. The SABER sensor horizontally observes the emission bands at a tangent point on the horizon. A motion-controlled scanning mirror is employed to obtain a vertical limb scan of the Earth's atmosphere. The limb scan altitude ranges from approximately 360 km above the Earth down to the Earth's surface. The TIMED satellite orbits the Earth 14–15 times in a 24-hour period, and SABER takes a scan approximately every 63 seconds to provide nearly 1400 scans a day.

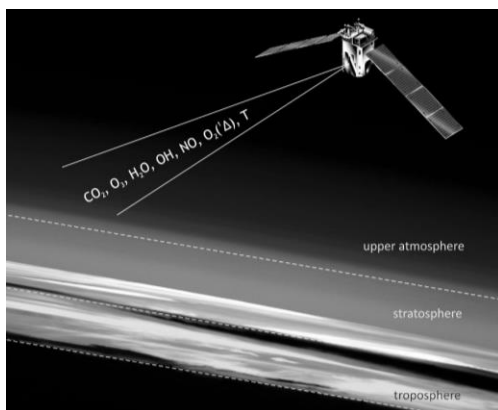


Figure 1. The SABER instrument aboard the TIMED satellite performing an atmospheric limb scan. [https://www.nasa.gov/sites/default/files/thumbnails/image/timed_grl_cover_image_0.jpg]

The SABER sensor incorporates 10 different channels to measure emissions from eight atmospheric gas species as depicted in Figure 2. The detectors are co-mounted on the same focal plane detector array to produce the composite field of view depicted in Figure 2. The rectangular field of view of each channel is approximately 2 km high by 60 km wide at the tangent point. Herein the focus will be on channel 4 (O₃ 9.3 μm), channel 8 (OH 2.06 μm), channel 9 (OH 1.64 μm), and channel 10 (O₂ 6.8 μm).

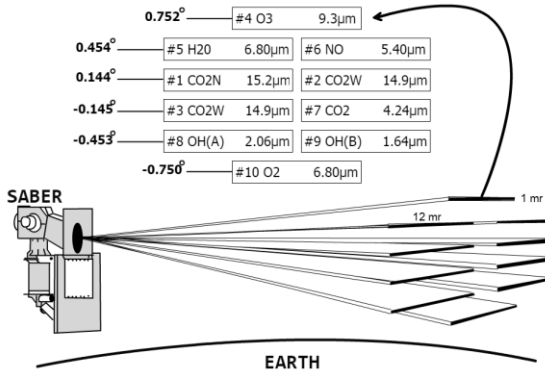


Figure 2. The SABER sensor focal plane channel locations. [<http://saber.gats-inc.com/operations/Yearly/includes/diagrams.html>]

Hydroxyl Airglow Photochemistry

The mesospheric airglow emissions from the hydroxyl, molecular oxygen, and ozone molecules of interest herein are produced by a complex set of photochemical reactions. Mesospheric hydroxyl airglow is produced when ozone, formed by the reaction of molecular and atomic oxygen with a third molecule, interacts with hydrogen atoms to produce vibrationally excited hydroxyl molecules plus diatomic oxygen. These excited OH molecules relax to lower energy levels, releasing photons. Examination of the altitude and intensity of these emissions provides insight into ozone production and depletion rates in the mesosphere. Long-term trends, such as the variations in the global 3-D airglow intensities over an entire solar cycle, provide clues to atmospheric energetics [<http://saber.gats-inc.com/>].

VER Profile Classification

Measurements used in the validation and analysis of the SABER hydroxyl, oxygen, and ozone profile data have revealed the occasional presence of unexpected profile features. These features may be present in both the limb emissions and/or the derived volume emission rates (VER). They are observed in some 15% to 23% of the emission profiles. Since such features may lead to inaccuracies in the analysis of VER profiles, it is important to establish the cause or causes of these anomalous airglow altitude profiles.

For convenience, the altitude airglow structures were categorized into three types of layers designated as (1) normal, (2) multiple peak, or

(3) bifurcated. Figure 3 shows representative nighttime profiles of the “normal” classification. Normally distributed profiles exhibit a near Gaussian shape with a single maximum. The examples of Figure 3 include the two OH channels and the O₂ airglow channel with maxima at about 87 km.

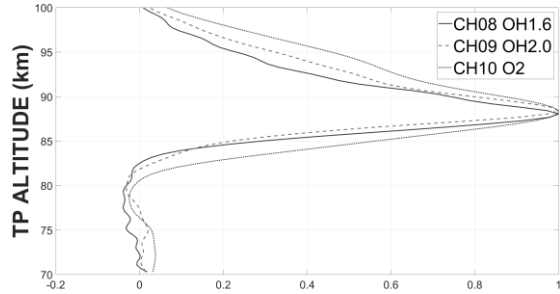


Figure 3. Typical derived normal nighttime VER tangent point (TP) profiles. [1 July 2009; Orbit 40960 Event 96].

Shown in Figure 4 are the source limb scan tangent point profiles from which the volume emission rate (VER) profiles of Figure 3 were derived. While these limb profiles exhibit a single maximum at about 84 km, it should be noted that limb profile peaks do not transform directly into VER profile peaks. VER profiles may be obtained by applying an Abel transformation to the source limb data. This transformation is sensitive to limb scan derivatives, so the small changes in the Figure 4 limb scans at about 87 km lead to the VER profile peaks of Figure 3.

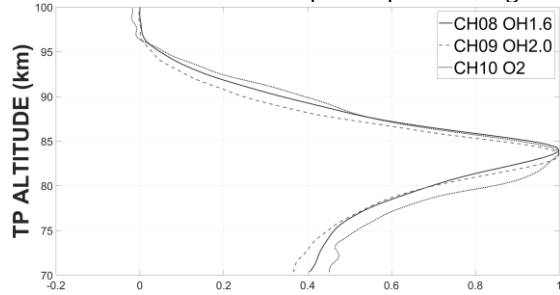


Figure 4. Typical nighttime normal limb-scan tangent point (TP) profiles used to derive the VER profiles of Figure 3. [1 July 2009; Orbit 40960 Event 96].

The second VER profile classification category is that of “multiple-peak” profiles. This type of profile exhibits a primary and a secondary peak spaced about 2 to 5 km apart. The example profiles of Figure 5 have

two peaks conforming to this classification; however, sometimes multiple-peak VER profiles have been observed with more than two peaks. The tangent point source limb scans used to derive the Figure 5 VER profiles are shown in Figure 6. Again, note the location of the slope changes in the limb scan compared with the corresponding VER profiles.

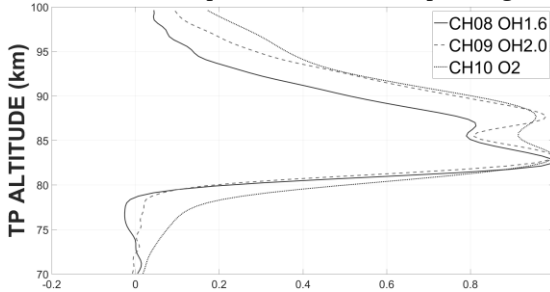


Figure 5. Typical nighttime multiple Peak VER profiles. [6 December 2009; Orbit 43316 Event 5].

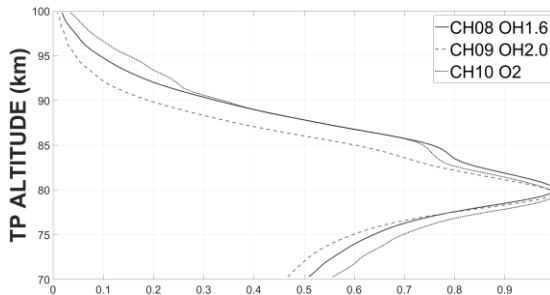


Figure 6. Nighttime multiple peak tangent point (TP) limb-scans used to derive the VER profiles in Figure 5. [6 December 2009; Orbit 43316 Event 5].

The third VER layer classification category is called a “bifurcated” profile. This category is similar to the multiple-peak category except that the primary and secondary peaks are spaced much more than 5 km apart. The analysis results for this category of profile will not be included herein.

Global Distribution of Multiple-Peak Profiles

The geographical distribution of hydroxyl 1.64- μm nighttime multiple-peak VER profiles plotted on a world map is shown in Figure 7 for the year of 2009. Each dot on this map represents the number of multiple-

peak profiles observed within a one-degree longitude by one-degree latitude square. Twilight and daytime profiles are not included on the map. The distribution density difference at high and low latitudes is due to the instrument orientation coupled with the satellite orbit.

Although there are significantly more multiple-peak profiles observed in the daytime than in the nighttime, the geographical distribution is similar. The geographical distributions for hydroxyl, oxygen, and ozone multiple peak VER profiles are also similar. For brevity, only nighttime hydroxyl 1.64- μm data are included from hereon. No significant geographical differences are apparent in the geographical distribution of Figure 7, leading to the probability that nighttime OH multiple peak VER profiles may not be directly linked to atmospheric mass-transport upwelling mechanisms.

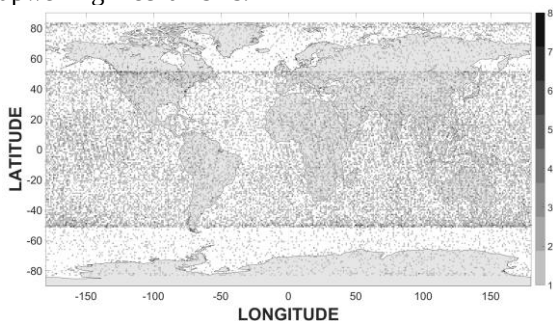


Figure 7. Geographic distribution of OH 1.64- μm nighttime multiple peak VER occurrence densities. [Data over the year 2009].

VER Profile Processing Instabilities

Oscillations with a period corresponding to about 2 km were observed in a significant number of limb scan and derived VER profiles. To determine if these oscillations are related to multiple-peak profiles, both the limb scans and the corresponding VER profiles were passed through a high-pass filter, leaving only 2 km and shorter periods.

Although some phase-shift variations occurred, the basic oscillation periods in both the limb scan and VER filtered profiles are about 2 km. In addition, after reviewing a large number of these filtered profiles, the oscillation period remains at about 2 km. All the corresponding unfiltered profiles contained primary-to-secondary spacings greater than 2 km. The purpose was to explore whether these 2-km period oscillations are the cause of multiple peaks but likely come from the initial limb-scan data.

Correlation of Hydroxyl and Ozone Profiles

The production of mesospheric hydroxyl airglow is photochemically linked with molecular oxygen and ozone in the same region. Ozone limb scans are available in the SABER data set, but the corresponding VER profiles are not. Ozone is optically thicker than hydroxyl, and thus it is more difficult to accurately transform the limb scan to a VER profile.

To obtain SABER VER profiles additional processing beyond a simple Abel transform is employed.¹ To make a valid comparison between the VER profiles of hydroxyl, molecular oxygen, and ozone, the SABER limb scans for each molecule have been transformed using the MATLAB Abel transform. The source limb scans are shown in Figure 8, and the corresponding MATLAB Abel transformations are shown in Figure 9.

The three limb scan plots of Figure 8 show a high degree of similarity as do the VER profile plots of Figure 9. This suggests the possibility that the hydroxyl multiple peaks are related to similar peaks in ozone.

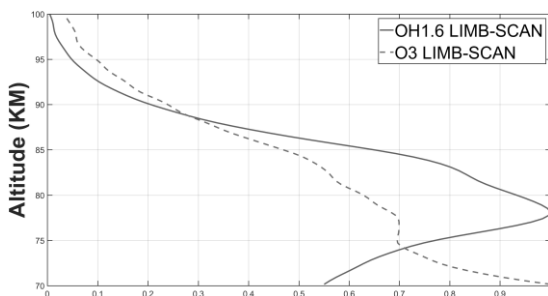


Figure 8. Typical nighttime OH 1.64 μm and O₃ limb scans. [1 January 2009; Orbit 38285 Event 20].

¹ The instrument signal is uncalibrated counts. Level 1 uses absolute counts converted using radiance calibration (using the IFC), coalignment of all channels in altitude, deconvolution of the FOV function for each channel and apodization using a Gaussian function; removes detector memory effects; and for the short-wave channels (8–10) estimation and removal of off-axis scatter. There are numerous steps in going from Level 0 data to Level 1B. [Email communication from B. Tom Marshall of GATS, Inc. to Brian Simons, 23 January 2018.]

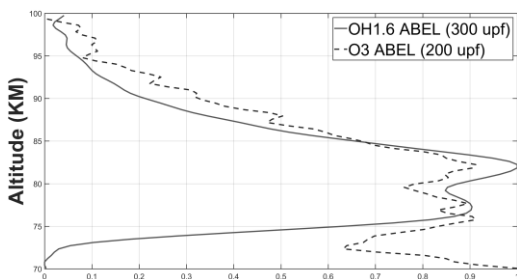


Figure 9. Abel transforms of Figure 8 limb scans. [1 January 2009; Orbit 38285 Event 20].

Conclusions

- Multiple-channel radiometers aboard low Earth orbit satellites comprise a beneficial technique to measure and study the mesosphere.
- No significant differences were observed in the geographical distribution of multiple-peak profiles, leading to the likelihood that they are not linked to atmospheric mass-transport upwelling mechanisms.
- The high-pass frequencies of the multiple-peak hydroxyl VER profiles and limb scan data are essentially the same for both hydroxyl channels and correspond to an altitude period of about 2 km. The primary-to-secondary peak spacing of many multiple peak hydroxyl VER profiles is greater than 2 km so instabilities in processing giving high-frequency oscillations might not be the source of hydroxyl multiple-peak VER profiles.
- The primary-to-secondary peak spacing of multiple peaks of the hydroxyl 1.64- μm VER profiles appear to be correlated with corresponding ozone multiple-peak VER profiles computed from the ozone limb scans. The limb scans of both channels also appear to be correlated. This leads to the prospect that the hydroxyl multiple peaks could be driven by photochemical reactions with ozone.
- Multiple-peak VER profiles were observed in less than 23% of all measured events of the SABER mission.

Acknowledgments

The contributions of GATS, Inc., for furnishing processed SABER data, plus the technical assistance by the NASA Langley Research Center, Hampton University, and Utah State University are acknowledged and appreciated.

Gender Differences in the Role of Acculturation, Self-Regulation, and Self-Esteem in Alcohol Consumption among Asian American Adults

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Abstract

Objectives: *This study uses multigroup structural equation modeling procedures to examine gender differences in the role of acculturation, self-regulation, and self-esteem in alcohol consumption among Asian American adults. Data were collected using online survey. A total of 3,493 surveyed Asian Americans aged 21 years or older were invited to participate. Of these, 891 Asian American adults who had consumed at least one alcoholic drink in the past 30 days participated in the survey (response rate: 25.5%). Multigroup structural equation procedures were used to examine the role of acculturation, self-regulation, and self-esteem in alcohol consumption. For men, self-regulation positively predicted alcohol consumption ($\beta = .49, p < .001$), but for women, self-regulation did not significantly predict alcohol consumption ($\beta = .02, p = .835$). In the male sample, acculturation negatively predicted alcohol consumption ($\beta = -.54, p < .001$), but in the female sample, acculturation*

positively predicted alcohol consumption ($\beta = .31, p < .001$). Self-esteem positively predicted alcohol consumption in men ($\beta = .67, p < .001$), but it negatively predicted alcohol consumption in women ($\beta = -.13, p < .001$). Relationships between self-regulation, self-esteem, acculturation, and alcohol consumption in Asian Americans differ by gender. The current analysis would be enhanced by a longitudinal design able to strengthen causal explanations. Future research should also take into account immigrants' generation.

Introduction

Alcohol consumption causes not only health issues but also legal and social problems. A strong correlation exists between alcohol consumption and an increased risk of developing diseases and illnesses such as alcoholism, cardiovascular disease, malabsorption, chronic pancreatitis, alcoholic liver disease, and cancer (CDC, 2004). Long-term use of alcohol will eventually damage nearly every organ and system in the body (Caan & Belleruche, 2002). Alcohol use is also associated with an increased likelihood of committing criminal offenses, including drunk driving, public disorder, child abuse, domestic violence, rape, burglary, and assault, as well as a commensurately greater risk of subsequent legal consequences (Isralowitz, 2004). Asian Americans—that is, Americans of Asian descent—make up 5.6% of the U.S. population (U.S. Census Bureau, 2012). National surveys have found that compared with other racial or ethnic groups, Asian Americans have a lower prevalence of alcohol consumption. Even so, longitudinal studies have indicated that 40% of Asian Americans drink alcohol regularly (Lee et al., 2013) and that they experience a higher rate of negative consequences from doing so than do drinkers from other ethnic groups (Cheng et al., 2012; Iwamoto, et al., 2012).

Various studies of alcohol consumption among Asian Americans have revealed several factors related to alcohol use, among them gender, marital status, genetics, sexual orientation, poverty, place of residence, and education (Grant et al., 2004; Hendershot et al., 2008). Other factors affecting the consumption of alcohol include affiliation with different social groups, social-cultural affiliation, acculturation and acculturation stress, and cultural observances (Park, 2011). Although the findings of previous studies indicate that self-esteem and self-regulation affect alcohol consumption among Asian Americans, these studies did not explore the role of acculturation and acculturation stress in alcohol consumption (Boyd et al., 2014; Cheng et al., 2012). Moreover, these studies were limited by focusing only on college-age and young adult subjects

(Luczak et al., 2014; So & Wong, 2006). Accordingly, the actual picture of alcohol consumption among Asian Americans might vary from that suggested by previous findings; incorporating acculturation and acculturation stress might yield different results, and the drinking patterns of older adults might not be similar to those of young adults. This study thus attempts to address the limitations of previous studies by developing and testing a model involving constructs that might particularly influence alcohol use among Asian Americans. Specifically, this study attempts to answer the following major research questions: What are the effects of self-esteem, self-regulation, and acculturation on Asian Americans' alcohol consumption? Are structural relations among such contributing factors similar for men and women?

The proposed relations to be tested in this study are shown in the hypothesized model depicted in Figure 1: Self-esteem (Lawing, 2006; Neighbors et al., 2004), self-regulation (Hustad et al., 2009; Quinn & Fromme, 2010), and acculturation (Karriker-Jaffe & Zemore, 2009; Zemore, 2007) were all expected to directly affect alcohol consumption. Self-esteem, a concept drawn from psychology, reflects a person's overall evaluation or appraisal of his or her own worth. Self-esteem encompasses beliefs and emotions such as triumph, despair, pride, and shame (Hewitt, 2009). Previous studies suggested that self-esteem, which includes the deriving of self-worth from met expectations, would mediate the relation of controlled orientation and drinking motives, thus predicting alcohol consumption and related consequences (Neighbors et al., 2004).

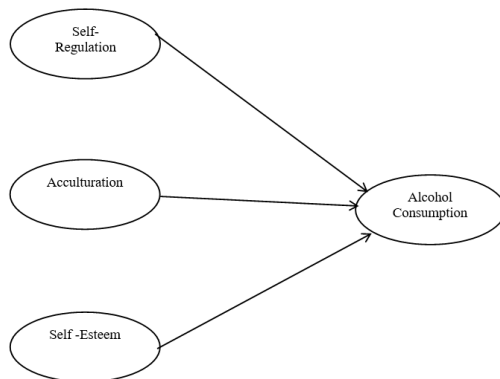


Figure 1. The proposed structural model of alcohol consumption.

People who have high levels of self-esteem are associated with significantly decreased drinking (Pedersen et al., 2013). Self-regulation refers to the ability to control one's own emotions, behaviors, and desires to obtain some later reward (Vohs et al., 2008). Studies have indicated that high self-regulation inversely predicted heavy episodic drinking as well as alcohol-related problems (Quinn & Fromme, 2010). Individuals who have a lower capacity for self-regulation are more likely to engage in drinking behavior and are less likely to maintain moderate use and avoid negative consequences; accordingly, those individuals are more likely to become relatively heavy drinkers (Hustad et al., 2009).

Acculturation refers to the process by which individuals learn the customs, attitudes, and behavioral characteristics of a host culture (Zane & Mak, 2003). Acculturation has been cited as a major factor pushing Asian Americans to adopt white Americans' alcohol consumption behaviors and patterns (Castro et al, 2009). The acculturated stress model, on the other hand, promotes the view that alcohol consumption among Asian Americans is related to high stress levels accompanying acculturation processes. According to the acculturation stress model, many immigrants turn to alcohol consumption as a way of coping with the stress accompanying acculturation (Ehlers et al., 2009).

Method

Participants and Procedures

This study was approved by Indiana University Institutional Review Board on the protection of human participants. The study employed a non-experimental cross-sectional design and used a convenience sample to collect data. The survey was sent to Asian American online panel members living in the United States; the online questionnaire was available for completion for about two months. Of the 3,493 Asian Americans invited to participate, 2,493 respondents didn't click the survey invitation link, 109 respondents dropped out after clicking the invitation link, and 891 successfully completed the survey (although 13 such surveys were missing some data). Thus the response rate of the study was approximately 25%.

Measures

The instruments used to measure the study variables were adapted from well-established scales. Rosenberg's Self-Esteem Scale (Rosenberg, 1965), the Miller and Brown Self-Regulation Questionnaire (SRQ;

Brown et al., 1999), and the Suinn–Lew Asian Self-Identity Acculturation (SL-ASIA) scale (Suinn et al., 1987) were used to measure self-esteem, self-regulation, and acculturation, respectively, with five items adapted from the Suinn–Lew Asian Self-Identity Acculturation (SL-ASIA) scale (Suinn et al., 1987) to measure acculturation. Participants were asked whether they read and wrote “only an Asian language,” “an Asian language better than English,” “both an Asian language and English equally well,” “English better than an Asian language,” or “only English.” Furthermore, participants were asked “If you consider yourself a member of the Asian American group, how much pride do you have in this group?” Answer choices included “extremely proud,” “moderately proud,” “little pride,” “no pride, but do not feel negative toward group,” and “no pride, and feel negative toward group.” Additionally, being asked “How would you rate yourself?” participants were given the following answer choices: “very Asian,” “mostly Asian,” “bicultural,” “mostly Westernized,” and “very Westernized.” Finally, respondents were asked “Do you participate in Asian occasions, holidays, traditions, and the like?” Answer choices included “nearly all,” “most,” “some,” “few,” and “none.”

Moreover, five items were adapted from Brown et al. (1999) to measure self-regulation on a 5-point Likert scale: “I am able to accomplish goals I set for myself,” “I have personal standards and try to live up to them,” “If I wanted to change, I am confident that I could do it,” “I can stick to a plan that’s working well,” and “I am able to resist temptation.” Five items were adapted from Rosenberg’s Self-Esteem Scale (1965) to measure self-esteem on a 5-point Likert scale: “I feel that I am a person of worth, at least on an equal plane with others,” “I feel that I have a number of good qualities,” “I am able to do things as well as most other people,” “I take a positive attitude toward myself,” and “On the whole, I am satisfied with myself.”

Data Analysis

Descriptive statistics were generated using SPSS 21 (IBM, 2012), and the AMOS 20 (Arbuckle, 2001) structural equation modeling (SEM) program was used to measure the effects of self-esteem, self-regulation, and acculturation scores on alcohol consumption. A two-step procedure was used to test the proposed model (Anderson & Gerbing, 1988). The measurement model was assessed first via a confirmatory factor analysis; once the model had acceptable fit, its constructs were tested for convergent and discriminant validity. Thereafter, the structural model was tested.

A multigroup analysis was also conducted to determine whether path coefficients were invariant across the samples of men and women, testing whether gender moderated the relationships between the study variables. Per Byrne (2001), the first step in a multigroup analysis is to determine whether the structural model fits groups of men as well as of women. Next, the two groups are tested simultaneously without constraining any of the path coefficients; this is the unconstrained model. Then the two groups are tested simultaneously, this time constraining all the path coefficients; this is the constrained model. If the change in chi-square between unconstrained and constrained models is statistically significant, then it is assumed that at least one path coefficient is not invariant across groups. Thus, to identify an invariant path or paths, simultaneous group analyses are successively conducted in which paths are constrained one at a time.

Results

Description of the Sample

Participants were aged 21–57 years; their mean age was 30.29 (*SD* = 9.88). As shown in Table 1, 57% of the sample was female. Slightly more than half the respondents were of Chinese descent (50.9%), 16.3% were Korean American, 9% were Asian Indian American, 7.6% were Filipino American, 5.6% were Vietnamese American, 5.6% were Japanese American, and 4.9% were of other Asian descent. Of these, 43% had a postgraduate degree, and 35.5% had a bachelor’s degree; all others had at most an associate’s degree. Approximately 43% of respondents were full-time students; 42.5% of respondents worked full-time, 13% worked part-time or were self-employed, and a minority was unemployed (1.6%). A third of the sample earned \$35,000 or less annually (27.7%), 47.5% earned between \$35,000 and \$75,000, and 24.8% earned more than \$75,000. Most respondents had started drinking between 16 and 20 years of age (69.9%) and reported having consumed alcohol on between one and five days during the past month (89.4%). Respondents indicated that the average number of drinks they consumed when they drank was between two and three (66.3%). The majority indicated that they had not engaged in binge drinking during the past month (71.8%).

Table 1 Summary of Sample Characteristics (<i>N</i> = 878)		
Variable	<i>n</i>	%
Gender		
Female	503	42.7
Male	378	57.3

Geographic location		
Northeast	233	26.5
South	169	19.2
Midwest	259	29.5
West	217	24.7
Ethnicity		
Chinese	447	50.9
Korean	143	16.3
Asian Indian	79	9
Filipino	67	7.6
Vietnamese	50	5.7
Japanese	49	5.6
Other Asian	43	4.9
Highest level of education		
Associate's degree or less	185	21.1
Bachelor's degree	312	35.5
Post-graduate degree	381	43.4
Employment status		
Full-time student	377	42.9
Full-time employee	373	42.5
Part-time employee	77	8.8
Self-employed	37	4.2
Unemployed	14	1.6
Annual income		
Less than \$35,000	243	27.7
\$35,000 to \$74,999	417	47.5
\$75,000 or more	218	24.8
Age started drinking alcohol		
15 years or less	162	18.5
16 to 20 years	614	69.9
More than 20 years	102	11.6
Days consumed alcohol in past month		
Don't drink	21	2.4
1 to 5	785	89.4
6 to 10	37	4.2
11 or more	35	4
Average number of drinks per time		
Don't drink	21	2.4
1	212	24.1
2 to 3	582	66.3
4 or more	63	7.2
Times binge drank in past month		
None	630	71.8
1 to 2	217	24.7
3 to 5	23	2.6
6 to 9	8	0.9

Results for the Measurement and Structural Model

The measurement model fit the data well. The values of all the fit indices exceeded their acceptable thresholds: Goodness of Fit (GFI) was .94, Comparative Fit Index (CFI) was .97, Root Mean Square Error of Approximation (RMSEA) was .04, and Standardized Root Mean Square Residual (SRMR) was .04. In addition, all indicator variables loaded significantly onto their respective constructs. The composite reliability and the average variance extracted were used to measure the convergent validity of the constructs. Constructs have convergent validity when the composite reliability exceeds the criterion of .70 (Hair, et al., 2010) and the average variance extracted is above .50 (Bagozzi, 1994). The composite reliability values of the constructs were above .70, and all average variance extracted values exceeded .50; thus, all constructs were deemed as having convergent validity. Discriminant validity was assessed by comparing the absolute value of the correlations between the constructs and the square root of the average variance extracted by a construct. When the correlations are lower than the square root of the average variance extracted by a construct, constructs are said to have discriminant validity (Fornell & Larcker, 1981).

The findings reveal that the square roots of the average variance extracted for all the constructs were higher than their correlations with other constructs; thus, these constructs had discriminant validity. The proposed structural model fit the data well. All the fit indices met their respective thresholds for acceptable model fit. The model accounted for 10.2% of the variance of alcohol consumption. Self-regulation did not directly affect alcohol consumption, $\beta = .05$, $p = .379$, but the following variables significant affected alcohol consumption: acculturation, $\beta = .14$, $p = .003$; self-esteem, $\beta = .13$, $p = .008$.

Results of the Multigroup Analysis

The findings reveal that the structural model fit both the male and female samples. The values of all the fit indices exceeded their acceptable thresholds: The GFI values were above .80, the CFI values were above .95, the RMSEA values were below .06, and the SRMR values were below .08. Accordingly, simultaneous group procedures were conducted. The results of the unconstrained and constrained model tests revealed that the change in chi-square between the unconstrained and constrained models was statistically significant: $\Delta\chi^2(9) = 225.74$, $p < .001$. Accordingly, simultaneous group procedures were conducted to determine which of the path coefficients were not invariant across groups.

As depicted in Figures 2 and 3, the path from self-regulation to alcohol consumption varied significantly across groups: $\Delta\chi^2(1) = 12.24$, $p < .001$. In the male group, self-regulation positively predicted alcohol consumption, but in the female group, self-regulation did not significantly predict alcohol consumption. The relationship between acculturation and alcohol consumption differed significantly across gender: $\Delta\chi^2(1) = 71.87$, $p < .001$. In the male sample, acculturation negatively predicted alcohol consumption, but in the female sample, acculturation positively predicted alcohol consumption. The path from self-esteem to alcohol consumption varied significantly across groups: $\Delta\chi^2(1) = 40.31$, $p < .001$. Self-esteem positively predicted alcohol consumption in the male sample; in the female sample, it negatively predicted alcohol consumption. Altogether, these findings suggest that gender moderated all the relationships posited in the structural model.

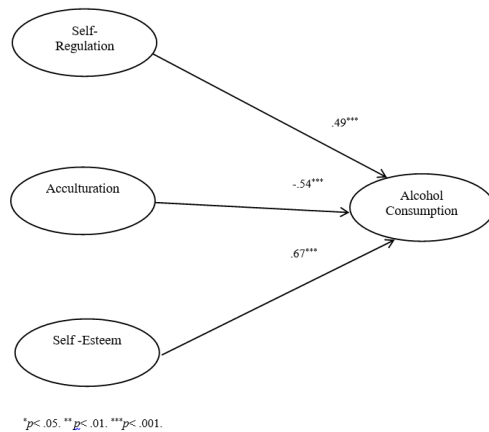


Figure 2. Standardized coefficients for the structural model within the sample of male participants.

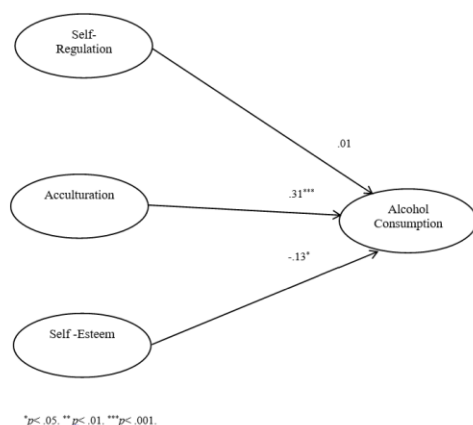


Figure 3. Standardized coefficients for the structural model within the sample of female participants.

Conclusions

In this study, although self-regulation did not significantly predict alcohol consumption, acculturation and self-esteem significantly predicted alcohol consumption. Moreover, gender moderated the effects of self-regulation, acculturation, and self-esteem on alcohol consumption.

The results of this study also suggest the existence of a positive direct relationship between self-esteem and alcohol consumption. High self-esteem might lead to certain actions that have negative consequences, such as drinking and smoking (Mills & Caetano, 2010). People who have high self-esteem might not be able to stand up for their beliefs and values when being judged by others. They often feel self-conscious and tend to engage in certain activities just to feel a part of the group. Accordingly, a person who has high self-esteem tends to do what everyone else is doing—such as drinking and smoking. A study conducted by Hahm et al. (2014) noted that Asian Americans often exhibit high self-esteem, possibly through a combination of sensitive nature, self-acceptance, and pressure from family members and other Asian Americans. Indeed, many Asian Americans drink and smoke to be a part of the community and to help themselves feel better (Hahm et al., 2014). Considering this study's findings, and in light of some research already mentioned, it is reasonable to suggest that those who have high self-esteem have a high propensity to consume alcohol because of their pressure to succeed, which creates stress, or out of a superiority complex, whereas those who have low self-esteem are likely to follow the crowd, consuming alcohol as a way of associating with those who are confident.

According to the results of data analysis, acculturation directly affected alcohol consumption in the entire sample, consistent with the findings of previous studies. Caetano (1987) noted that more acculturated minorities, such as Hispanics, drank more frequently than less acculturated ones in a number of social settings. Wagner et al. (2008) also suggested that acculturation could lead to alcohol consumption.

The effects of acculturation varied across male and female participants in this study. Acculturation negatively predicted alcohol consumption in the male sample but positively predicted alcohol consumption in the female sample—a finding supported by studies of other ethnic groups. Previous research among Latino Americans showed a positive association between acculturation and alcohol use for women, whereas men showed the opposite (Raffaelli et al., 2007). Caetano et al. (2008) also suggested that men drank less as they acculturated and had a lower prevalence of alcohol-use disorders, whereas women drank more with acculturation.

However, the findings were not consistent with those found in previous literature focusing on Asian Americans. Hendershot et al. (2008) suggested that Asian American women with higher acculturation reported lower alcohol use than did men. Juon et al. (2003) indicated that Asian American men seemed to be economically better off than women were and had a longer duration of residence in the United States. Compared with men, women had limited English skills. Accordingly, Asian American men are more likely to adapt to their host culture in the United States, adopting behaviors such as smoking and drinking. A recent study conducted by An et al. (2008) also suggested that acculturation was not a key factor influencing risky behavior such as cigarette smoking and drinking among Asian American women (An et al., 2008).

Beyond finding differences between men and women regarding acculturation and drinking habits, this study also found differences in levels of self-regulation and self-esteem, noting that the relationship between self-regulation and alcohol expectancy among men was not statistically significant but that self-regulation negatively predicted alcohol expectancy among women. This finding is at variance with those of several other studies. For example, Udo et al. (2009) found no significant gender differences of self-regulation and alcohol expectancy between men and women. Again, these findings might be tied to the questions asked in the studies or even the way in which each respondent perceived his or her ability to self-regulate when using alcohol.

Though the present study found an overall positive relationship between self-esteem and alcohol consumption, findings varied for men and women. Men were found to have a positive relationship, which correlates

with overall findings, but women were found to have a negative relationship. Walitzer and Sher (1996) support the findings of the present study, noting that women are more prone than men to alcohol problems resulting from low self-esteem. Furthermore, Walitzer and Sher identified self-esteem as a good predictor of future alcohol use among women but not among men.

Limitations and Future Recommendations

Because this study was cross-sectional and non-experimental, causal interpretations cannot be put forth. The current analysis should be enhanced by a longitudinal design that can strengthen causal explanations while taking immigrants' generation into account. Indeed, studies of the effects of acculturation on drinking behavior among different generations have found significant differences among generations. For example, Markides et al. (1988), in a three-generation study of Mexican Americans, reported that acculturation was not related to alcohol consumption in the older generation. On the other hand, a study focusing on Asian Americans revealed that first-generation South Asians, especially females, were more likely than their parents to consume alcohol (Becerra et al., 2013). This study contributed to the literature regarding Asian Americans and some of the social-psychological factors that influence their alcohol consumption, with acculturation, and self-esteem affecting alcohol consumption. Furthermore, relationships between social-psychological factors and alcohol consumption differ across gender groups.

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Unique Rituals, Pre-Performance Routines and Superstitious Behavior used by Elite Senior Athletes

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Abstract

Qualitative research methods were employed to analyze and gain insight into how elite senior athletes experience or engage in unique rituals, pre-performance routines, and superstitious behavior. The investigation and information calculated will assist in providing better understanding of how these personal elements are exhibited by elite senior athletes participating in a range of athletic events. A nine-point survey/questionnaire was designed and personally administered to illuminate the variety of unique characteristics and commonalities associated with this fascinating behavior. A mixture of questioning techniques were employed, including a Likert scale, yes/no responses, and open-ended questions. In conclusion, a majority of the responses indicated that both before and during athletic competition, such rituals, routines, and superstitious behaviors were practiced.

Introduction/Purpose

Research Question: Do senior elite athletes use unique rituals, pre-performance routines, and superstitious behaviors in athletic sports? If so, what types of rituals, routines, and superstitious behaviors are performed? The purpose of the research was to understand common themes of behaviors and how athletes believed it influenced performance.

As part of an on-going investigation into the elusive events behind elite senior athletes routines and an ever-increasing number of elite senior athletes pursuing and participating in organized competitive physical activities, additional research is needed and would help illuminate the real advantage of performing a consistent routine or superstitious behavior.

Purpose of the Study: Understand whether pre-performance routines, rituals, and superstitious behaviors are used within a sample size of elite senior athletes. If such behaviors are performed, this research will look at common themes of routines that may help the athlete feel confident in its effect.

Definitions

There are three phrases that are important to define. First, “unique rituals” (UR). According to Schippers & Van Lange (2006, p. 2533), UR are defined as unusual, repetitive, and rigid behavior that is perceived to have a positive effect by the acting individual.

The second phrase to be defined is “pre-performance routine” (PPR). PPR will be defined as a set of cognitive and behavioral elements that an athlete systematically engages in before performance execution (Cotterill, 2010).

The last phrase being defined is “superstitious behavior” (SB), actions that are repetitive, formal, sequential, and distinct from technical performance and that the athletes believe to be powerful in controlling luck or other external factors (Bleak & Frederick, 1998, p. 2).

Methods

Design of the Study

Data for this case study to develop grounded theory were collected over a 2-week period at the World Senior Games in St. George, Utah (October 9–21, 2017). The research instrument consisted of a nine-point survey/questionnaire designed to illuminate the unique rituals, pre-performance routines, and superstitious behavior commonalities and differences associated with the participants. Questions on the questionnaire

consisted of Likert-scale type/degree, fill-in-the-blank/opened ended questions. The questionnaires were personally administered by the researchers.

This research provided information and insight and helped to develop grounded theory into not only whether senior elite athletes participate in UR, PPR, and SB but also how athletes use certain behaviors and their belief about performance level increase.

As researchers, we sought to generate a discussion with participants to help define terms such as PPR, UR, and SB. In doing so, the athlete was able to more fully understand each question. Creating discussion also allowed the participant to feel comfortable with the questions being asked. As a way to ensure credible answers, we made sure the athlete had enough time to accurately complete the survey.

Results

Data from the study were retrieved from 112 responses to the research instrument (survey/questionnaire). Fifty-five male and 57 female participants ranging in age from 50 to 79 years (41 aged 50–59 years; 50 aged 60–69 years; 21 aged 70–79 years) who were actively engaged in a variety of sports responded. The most popular sports among the participants were softball, pickle ball, and basketball.

A series of qualitative questions help illuminated and describe the participant's unique experiences of participating in UR, PPR, and SB. Our results suggests that, 66% of the participants used UR, PPR, and SB. Their individual descriptions or explanations were both unique and demonstrated a wide variety of UR, PPR, and SB (see appendix Questions 2, 4, 5, 7, and 8).

Discussion

This research provided information and insight and helped to develop grounded theory into the commonalities of UR, PPR, and SB. This research found that such behaviors are more common than not. Elite senior athletes who do not engage in such behaviors may consider the positive experiences of elite senior athletes who do participate in such behaviors.

It also serves to promote an increased awareness with each senior elite athlete about their specific reasons for using UR, PPR, and SB. In general, athletes that actively used such routines believed that it did influence their athletic performance. Although our research cannot verify whether sport performance was in fact improved, because the athlete believes this, it is a routine that can be considered positive. Our research

cannot verify actual sport performance and should be considered in future research.

While elite senior athletes used routines to improve sport performance, a common experience when practicing UR, PPR, and SB is physical calmness. Based on the responses of elite senior athletes, a person who may experience stress or sport performance anxiety may benefit from such routines.

Conclusion

This study clearly demonstrates that more elite senior athletes participate in UR and PPR than do not. Such practices had a positive influence on preparation and performance for the athlete. Certain responses were common for PPR including, stretching, breathing and listening to music, whereas SBs were less commonly used within the athletes and behaviors/beliefs were extremely diverse.

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Appendix

Question 1 – Do you perform or engage in any ritual or performance routines before competing in an athletic event?

Male Participants: 32% responded Yes, 17% responded No.

Female Participants: 34% responded Yes, 17% responded No.

Question 2 – Please describe in a few words the behavior or thought process you employ in performing that routine ritual.

Male Participant Sampling	Female Participant Sampling
“I always chew Hubba Bubba Bubble Gum before each game.” “I wear my lucky #13 jersey.” “Drink a Mountain Dew, avoid stepping on the baseline.”	“Don’t look at the competition bracket.” “Take a deep breath before I serve” “Have to wear a hat.”

Question 3 – Do you use or rehearse any strange, weird, superstitious or peculiar behavior in preparing to compete in an athletic event? (Yes or No)

Male Participants: 20.5% responded Yes, 28.5% responded No.

Female Participants: 16% responded Yes, 35% responded No.

Question 4 – Please describe in a few words your superstitious behavior.

Male Participant Sampling	Female Participant Sampling
“Have to wear a necklace” “I will not remove a leaf on the court” “Tap ball against paddle”	“Wear the same underwear” “Drink a beer to help calm me down” “Stretch the exact same way”

Question 5 – Does your ritual, routine, superstitious behavior or pre-performance activity have a special meaning to you? Explain.

Male Participant Sampling	Female Participant Sampling
“For my mom” “Helps keep me focused” “Not really”	“I wore that shirt when I won” “Yeah, it’s just a mental thing” “Yes, it calms me down”

Question 6 – How often do you use this ritual, routine or superstitious behavior?

Almost always: 31%

Frequently: 4%

Occasionally: 5%

Seldom: 10%

Never: 49%

Question 7 – Do you believe that these rituals, routines, or superstitious behaviors enhance or have a direct effect on your athletic behavior performance?

Male Participant Sampling	Female Participant Sampling
“Yes, I shoot a higher percentage” “Had success” “Helps keep me focused” “Possibly”	“In a small limited way” “I sure hope so” “It’s just comforting” “Yes, I feel like my serve is more consistent”

Question 8 – Do you believe that these rituals, routines, or superstitious behavior increase control, instill confidence or increase athletic success?

Male Participant Sampling	Female Participant Sampling
“I feel more in control” “Yes, helps stay focused” “Yes, when I am consistent”	“Yeah, it keeps me calm” “Kinda if you win, yes.” “Matter of self-confidence”

Question 9 – Will you continue to use rituals, routines and superstitious behavior in the future?

Participants that said yes: 68%

Participants that said no: 29%

Participants that said sometimes: 4%

Mark Twain's Geographic Imagination in *Life on the Mississippi*

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Abstract

Twain's relationship to and understanding of place is characterized by robust sense of nostalgic identification and attachment. Yet Twain demonstrates in Life on the Mississippi that place is inherently open and always in process. For Twain, place is more event than static object, more verb than noun. Rather than fixed and unchanging, it is an articulated moment in an ongoing and neverending process of change (both social and "natural") and a constant reordering of a constellation of social relations. Through an investigation of Life on the Mississippi, this paper explores Twain's articulation of a nostalgic and portable sense of place that ultimately resists what he sees as the inherent instability and inevitable dissolution of place. In doing so, Twain anticipates present-day geographers like Doreen Massey by recognizing the radical openness and constant changeability of place. Indeed, by detailing the physical and cultural history of the Mississippi river, and through his elaborate description of his education as a riverboat pilot, Twain suggests that place itself can be preserved only in memory and only by those properly trained to read it. In addition, the paper will explore recent

critical debates on the nature of space and place, the relationship between temporality and spatiality, human interactions with landscape and environment, as well as the tensions between the local and the global.

Few writers have observed the geography of the Mississippi River as carefully as Mark Twain. In *Life on the Mississippi* (1883), Twain recalls his apprenticeship as a cub pilot on the Mississippi and his intense education of the river's complex and ever-changing geography. "There's only one way to be a pilot," a young Twain is told by the pilot Mr. Bixby, "and that is to get this entire river by heart. You have to know it just like A B C."¹ Later, Twain learns that through diligent study the "face of the water, in time, became a wonderful book" that could be read by the river-educated and which in turn would yield up its secrets.² For the would-be pilot, reading the river involved learning a new vocabulary, or a range of subtle signs in the river that signaled the presence of snags, sawyers, shoals, stumps, and sandbars, among other hazards, any of which could prove perilous to the navigation of a 200-foot Mississippi steamboat. "In truth," Twain explains, "the passenger who could not read this book saw nothing but all manner of pretty pictures in it, painted by the sun and shaded by the clouds, whereas to the trained eye these were not pictures at all, but the grimmest and most dead-earnest of reading-matter."³ Careful reading practices, then, allowed Twain to skillfully pilot riverboats, but the Mississippi offered him other readings and lessons as well.

Twain's river in *Life on the Mississippi* functions not only as a "book," one that can be read for clues on the physical makeup of the river or as a guide to piloting, but also as a geographical pedagogy or method for reading geography itself. I argue in the following pages that Twain employs the river as a guide for reading *cultural* geography rather than *physical* geography only, and in so doing he anticipates recent critical debates on the nature of space and place. Through careful presentation of the river's incessant volatility and changeability, and through accounts of human interactions with and historical events along the river, Twain envisions a space that is radically open, relational, in process, and interconnected, and likewise at odds with essentialist notions of the static, bounded, absolute, complete, or "authentic" location or natural feature. For Twain, then, learning to read the river meant learning something profound about how culture itself occupies or emerges from particular landscapes and spaces. Such spatial theorizing, moreover, suggests a broader

¹ Mark Twain, *Life on the Mississippi*, ed. James M. Cox (New York: Penguin, 1985), 76.

² *Ibid.* 95.

³ *Ibid.*

political reading of Twain's *Life on the Mississippi* than his critics have allowed, a reading focused on the constructed nature of both human and natural identities and the genuine openness of an American future outside the grand narratives of "Progress," "Development," or "Improvement" then popular.

Such an understanding of *Life on the Mississippi* contrasts with notions of Twain as an intensely place-based writer whose depictions of riverboat towns like Hannibal, Missouri, have become iconic and even nostalgic representations of the rooted, authentic, and static space. Indeed, the very framing of *Life on the Mississippi* involves the adult Twain's supposed return to the river of his childhood—that is, to a "home" or familiar place with rich emotional and physical connections. "After twenty-one years' absence," Twain writes, "I felt a very strong desire to see the river again, and the steamboats, and such of the boys as might be left; so I resolved to go out there."⁴ But my point is that, in *Life on the Mississippi*, Twain repeatedly invokes the familiar narrative of returning home as a time-altering act of nostalgic performance, only to subvert this act by emphasizing the ever-changing nature of place. In the end, I believe that it is only through memory—only through the *longing* to return home—that Twain ultimately manages to fix or stabilize place. Through the memory of the writer, akin to the memory exercised by the skilled riverboat pilot, place can be stabilized and realized—even politicized—as a kind of overlay on the changed and changing face of the present. Place is thus simultaneously static and dynamic, fixed and arbitrary. In a sense, it is also made portable, so that the human subject in any given place adheres at will to the old familiar things. Presumably, even Huck, as he "light[s] out for the territories," will take something of "home" with him.

Twain's Critical Pedagogy

Twain's education as a pilot was intensely geographic. His learning to "read" the river involved studying the river's contours, its ever-shifting channel, its fluctuating depth, its protean riparian zone, and its changing shorelines. To explain his "reading," he employed a subtle vocabulary of floating logs, slanting light, faint dimples, "tumbling 'boils,'" lines and circles, and silver streaks on the water.⁵ His success as a pilot, moreover, depended on his correct pairing of language and

⁴Ibid. 167.

⁵Ibid. 94-6.

place.⁶ Of course, a failure to know the river's alphabet and to interpret its language could carry grave consequences: Twain's education was a lesson of necessity. "The passenger who could not read [the river]," writes Twain, "was charmed with a peculiar sort of faint dimple on its surface [...]; but to the pilot that was an *italicized* passage; indeed, it was more than that, it was a legend of the largest capitals, with a string of exclamation points at the end of it; for it meant that a wreck or a rock was buried there that could tear the life out of the strongest vessel that ever floated."⁷ Of course, Twain does not intuit this new vocabulary. His knowledge of the river derives largely from Mr. Bixby, an expert pilot and Twain's river mentor, who teaches Twain his "A B C[s]"⁸ and how to decipher the text (the "dead language") of the river.⁹ His education, moreover, involved more than learning to read the river's subtle signs and extended to learning a vast geography in apparently minute detail. Having kept a notebook that "fairly bristled with the names of towns, 'points,' bars, islands, bends, reaches, etc.,"¹⁰ Twain explains that as a young pilot he had to learn not only "the names of all the towns and islands and bends, and so on, by heart, but I must even get up a warm personal acquaintanceship with every old snag and one-limbed cottonwood and obscure wood pile that ornaments the banks of the river for twelve hundred miles." With characteristic overstatement, Twain insists that he was required to know all these elements even in the dark.¹¹ During this mandatory learning process, Twain and many other riverboat pilots apparently became experts in reading and interpreting the Mississippi River landscape.

Twain's education extended to an understanding of human and cultural geography bound to the Mississippi, an understanding that Twain in turn embeds in his river narrative. Twain's descriptions of the river,

⁶ The name "Mark Twain" is, of course, Samuel Clemens's penname and is intimately linked to the river as a measurement of its depth and to his work as a pilot. The term "mark twain," shouted by riverboat men, signaled a measurement of "two fathoms"—sufficiently deep for safe navigation. However, the term also indicated a questionable water depth, a depth barely adequate, as James Cox emphasizes in his introduction to *Life on the Mississippi* when he explains that the term signaled "dangerous passage and not the safe water that Mark Twain on another occasion said the term denoted." See James M. Cox, introduction, *Life on the Mississippi*, op. cit. 19. In addition to providing Clemens a pen name, the river was the source of names for several Twain characters, including Tom Sawyer, whose surname derives from "sawyer," a submerged log that was a great danger to boats.

⁷ Twain, *Life on the Mississippi* 94.

⁸ Ibid. 76.

⁹ Ibid. 94.

¹⁰ Ibid. 77.

¹¹ Ibid. 80-1.

including its natural history, physical features, topography, channel location, and patterns of flow, all serve as a kind of pedagogy for reading geography. As Twain describes his slow and necessarily patient education as a riverboat pilot, he is simultaneously inculcating his readers with critical attitudes toward and habits of geographical interpretation. Twain uses the river to illuminate physical and abstract ways of reading spatial relationships among entities and locales, such as inherent tensions among the local, regional, and global; variations among cultural groups; the functioning of diverse societies; and theorized representations of place. Thus, just as Thoreau's *Walden* is far more than a how-to manual for living in the woods, Twain's *Mississippi* is a carefully nuanced text with a far broader reach than the natural aspects of the river.¹² In its casting of the river itself as a book, Twain's text is a pedagogical book about a pedagogical book. As I have already stated, this pedagogy is also inherently political, especially insofar as it incorporates the river's human geography which, in turn, is premised in part on the spatial play of social justice. Twain's pedagogy arguably seeks to accomplish what Ian Shore has referred to as "habits of thought, reading, writing, and speaking which go beneath surface meaning[s], first impressions, [and] dominant myths [...] to understand deep meaning[s], root causes, social context[s] and] ideolog[ies]."¹³

The Body of the Nation

Twain begins his geography lesson in the opening pages of *Life on the Mississippi* by highlighting the river's extensive reach and its relational interconnectedness, while simultaneously setting up an ironic contrast with his epigraph, a contrast that he will develop throughout the book. His choice of epigraph, which he titles "The 'Body of the Nation,'"¹⁴ serves not only to command attention to the geographic expansiveness and overall immensity of his project—that is, the expanse and immensity of the Mississippi River—but also to suggest a parallel between the river and its human spaces and places. "But the basin of the Mississippi," it reads, "is the Body of the Nation. All the other parts are but members, important in themselves, yet more important in their relations to this. Exclusive of the Lake basin and of 300,000 square miles in

¹² I do not mean to diminish or subordinate the task of learning the natural features of the river, but rather to emphasize the different though related projects of education taking place in Twain's narrative.

¹³ Ian Shore, *Empowering Education: Critical Teaching for Social Change* (Chicago: U of Chicago P, 1992), 129.

¹⁴ Drawn from the Editor's Table, "Indivisibility of the Nation," *Harper's Magazine*, February, 1963: 413-8.

Texas and New Mexico, which in many aspects form a part of it, this basin contains about 1,250,000 square miles.”¹⁵ As the textual entrance to the narrative, the passage establishes the vast scope of Twain’s geographic undertaking. In discussing “life” on the Mississippi, Twain engages an enormous geographical region and its expansive sweep of human and physical relationships, where human tributaries of the river are far more complex than its physical ones. Indeed, the personification of the river as a “Body” implies that its constituent parts, though “important” in themselves, exist only in relation to one another.

The Mississippi’s physical geography emphasizes its own interconnectedness. “No other river,” Twain writes, echoing his epigraph’s depiction of the river’s geographic reach, “has so vast a drainage-basin: it draws its water supply from twenty-eight States and Territories; from Delaware, on the Atlantic seaboard, and from all the country between that and Idaho on the Pacific Slope.”¹⁶

But Twain’s epigraph has a far more important rhetorical purpose. It is an unusual choice, a brief passage from a Civil War–era, anti-succeSSIONIST editorial published in *Harper’s* in early 1863, an editorial arguing for the nation’s geographic and spiritual integrity. Seemingly in sharp contrast to the initially mundane geography of *Life on the Mississippi*, the editorial responds to Lincoln’s second annual message to Congress (1862)—and especially to Lincoln’s famous evocation of the “great body of the Republic.”¹⁷ Fully supportive of Lincoln’s rhetorical vision, the editorial insists that “a nation, like an individual, consists of body and soul. Its soul is its people; its body is the territory they inhabit.”¹⁸ Embracing a form of geographic determinism (“the whole course of human history has been prescribed and prophesied in the physical structure of the globe”¹⁹), the editorial finally asserts the natural inevitability of the nation’s geographic law, allegedly “written in the physical structure of our land and in the development of our people” and declaring “that the American nation is divinely ordained to be one and indivisible.”²⁰

Twain’s epigraph serves two important rhetorical purposes. First, as I have already discussed, it indirectly establishes the magnitude and reach of the Mississippi River Basin, together with the interconnectedness and relationality of American physical and human geography. Second, and more importantly, the epigraph functions ironically as the target

¹⁵ Twain, *Life on the Mississippi*, epigraph.

¹⁶ *Ibid.* 39.

¹⁷ Editor’s Table 413.

¹⁸ *Ibid.*

¹⁹ *Ibid.*

²⁰ *Ibid.* 418.

of Twain's argument. I believe Twain takes issue with the United States as a personified body and that his own geographic vision is not only at odds with but seeks to undermine any vision of space—especially national space—as fixed, predetermined, and somehow authentically coherent. Twain would agree with Angus Fletcher that the very act of personification situates the agent (the US, in this case) as always “frozen into an eternally fixed form” (i.e., a particularized and finite body).²¹ By embodying the US, so to speak, Lincoln and others effectually impose a stable regime of meaning upon an abstract and fluid space. Within such a formulation, space is not only fixed and closed but determined and ephemeral. Doreen Massey puts matters more bluntly, asserting that, through personification, space is “always already divided up,”²² turning geography into history and space into time.²³

Twain finds the personification of the American space problematic in several ways. First, because it is bound to one historical trajectory or narrative, it points to a single future and denies the agent—here, the United States—any power to create or determine its own future. As Wai-chee Dimock suggests, the agent locked within such personification can take no “narrative action”—and because such action is, for the agent, “no more than an autotelic function, no more than the reflexive unfolding of what is already an ontological provision,” the agent only “enacts an edifying career of destined progress.”²⁴ Second, the notion of a fixed and destined national space whitewashes the history of its own formation, including the establishment of its borders, and represses the bold facts of war, broken treaties, and annexation.²⁵ Finally, such personification glories in the trappings of imperialism. Constructed as body, a nation needs spaces to grow, rest, eat, and work, and it will subsume such spaces—Cuba, the Philippines, Hawaii, Mexico—into its predetermined narrative of self.

The Geography of the River

Twain's depiction of the openness and changeability of the river (and, by extension, the openness and changeability of place) is obviously and directly at odds with a notion of nation as indivisible body. Twain frequently notes the Mississippi's propensity to shift directions, to

²¹ Angus Fletcher, *Allegory: The Theory of a Symbolic Mode* (Princeton: Princeton UP, 2012), 66.

²² Doreen Massey, *For Space* (Los Angeles: Sage, 2005), 6.

²³ *Ibid.*

²⁴ Wai Chee Dimock, *Empire for Liberty: Melville and the Poetics of Individualism* (Princeton: Princeton UP, 1991), 25.

²⁵ *Ibid.*

change its channel, to erode its banks, to build or shape or destroy surrounding land. The banks of the Mississippi, according to Twain, are in an almost constant state of formation and reformation, sometimes through radical means like the “cut-off”:

The Mississippi is remarkable in still another way—its disposition to make prodigious jumps by cutting through narrow necks of land, and thus straightening itself. More than once it has shortened itself thirty miles at a single jump! These cut-offs have had curious effects: they have thrown several river towns out into the rural districts, and built up sand bars and forests in front of them. The town of Delta used to be three miles below Vicksburg: a recent cut-off has radically changed the position, and Delta is now *two miles above* Vicksburg.²⁶

“Both of these river towns,” Twain adds, “have been retired to the country by that cut-off.”²⁷ Such cut-offs wreak havoc with the order, stability, and health of the personified body. If the American nation is “by the law of *nature* one and indivisible,”²⁸ as the editors of *Harper’s* suggest, what is the reader to make of Twain’s *nature* as radically open, unfixed, and subject to sudden changes that reorient entire towns and surrounding landscapes?

Also in conflict with the fixed “body of the Republic” is Twain’s portrayal of the incidental roles of humanity in natural processes, including processes which create or mark or erase place. In one important passage, Twain depicts the slow, long process of land formation along the Mississippi:

The mud [carried by the river], solidified, would make a mass a mile square and two hundred and forty-one feet high. The mud deposit gradually extends the land—but only gradually; it has extended it not quite a third of a mile in the two hundred years which have elapsed since the river took its place in history but over two hundred miles in 120,000 years.²⁹

Twain’s language suggests the unclear demarcations between land and water, solidity and fluidity, stasis and movement. The land was and always is under fluid-like destruction and construction. Just as soil from

²⁶ Twain, *Life on the Mississippi* 40.

²⁷ Ibid.

²⁸ Editor’s Table 413.

²⁹ Twain, *Life on the Mississippi* 40.

throughout the Mississippi River Basin slides, drains, erodes, or collapses into the river or its tributaries, so too does the river build up the rich, alluvial lands—albeit at a geologic pace—eventually becoming home to human settlements. The glacial pace of the “mud deposit,” however, sets everyday human activity in sharp relief against the patient scope of natural change. Not only does Twain undermine the notion of a stable national space predetermined by “nature,” he shows how the very idea of “nation” is diminished in the shadow of 120,000 years of riparian process.

Writing just two years earlier in *A Tramp Aboard* (1831), Twain describes his travels along glaciated landscapes in Europe, his hikes along moraines, and his camp atop a European glacier. When Twain and his travel companions contemplate how best to get back to the nearest town, they humorously conclude to ride the glacier, which Twain likens to steamboat travel—in that the glacier was “moving all the time” and carving up the landscape as it did so.³⁰ But after realizing that “we did not seem to be gaining any on the scenery,” Twain concludes that “this confounded thing’s aground again.”³¹ He writes:

“The Gover Glacier travels at an average rate of a little less than an inch a day.” [...] One inch a day, say thirty feet a year; estimated distance to Zermatt, three and one-eighteenth miles. Time required to go by glacier, A LITTLE OVER FIVE HUNDRED YEARS! [...] I revealed to Harris the fact that the passenger part of this glacier—the central part—the lightning-express part, so to speak—was not due in Zermatt till the summer of 2378, and that the baggage, coming along the slow edge, would not arrive until some generations later [...].³²

Although a richly comic episode, the passage proves at least two things: first, that Twain was well acquainted with glaciated landscapes and the constant change they wrought upon the land, albeit at a glacial pace; and second, that Twain curiously connects the glacier, by inference, back to the Mississippi River. The passage certainly resonates with the opening chapters of *Life on the Mississippi*, wherein Twain describes the scope and physical history of the Mississippi through claims like the following: “Nearly the whole of that one thousand three hundred miles of old Mississippi River which La Salle floated down in his canoes, two

³⁰ Mark Twain, *A Tramp Abroad* (Hartford, CT: American, 1899), 453-6.

³¹ *Ibid.*

³² *Ibid.*

hundred years ago, is good solid dry ground now.”³³ By connecting the glacier to his experiences on steamboats, Twain suggests parallels between the slow upheaval of landscape by a glacier and a river’s insistent, ever-changing imprint on its banks.

For Twain, human places are similarly in process and perpetually under construction. As Doreen Massey asserts, human spaces can be imagined as “articulated moments in networks of social relations and understandings” rather than as bounded, secure, homogenous, fixed, or fully coherent.³⁴ In this sense, the human place is no secure ontological object but more a process or event significant during a given moment in time and defined by its connections with other such places in the world—with what William Cronon has called “the paths out of town.”³⁵

Twain develops the idea of place as process in *Life on the Mississippi* in part by establishing, as we have seen, the relational and interconnected nature of the river itself, but also by highlighting the interconnectedness of specific locales along the river, as well as the layered histories that, like the river’s sediment that accumulates over time, build up or erode to make place an ever-changing product of multiple histories. If the river for Twain is a great confluence, then the land along the river and its various towns and villages are products of human convergences and historical interactions. Twain demonstrates this phenomenon by illustrating in the book’s opening pages the multi-cultural history of the area along the river. For instance, Twain briefly describes the journeys of the many explorers who traveled throughout the region and who at one time held claims upon the allegedly predestined “body of the Republic”—explorers such as Hernando de Soto, Louis Joliet, and later René-Robert de la Salle. Of course, space and place are never firmly rooted, much less immemorial, and land boundaries and land ownership are, by definition, fluid and temporary. Especially in the case of valuable lands along the Mississippi, possession was often worked out through conflict and violence.

As Twain suggests in his discussion of the river’s history, geopolitical boundaries are not established by Providence, nor do they possess unproblematic and internalized histories, but rather they result from historical struggle, treatises, warfare, and annexation. Recalling the history of settlement along the Mississippi River (and elsewhere), Twain particularly notes white exploitation of Native Americans:

³³ Twain, *Life on the Mississippi* 41.

³⁴ Doreen Massey, “A Global Sense of Place,” *Space, Place and Gender* (Minneapolis: U of Minnesota P, 1994), 154.

³⁵ William Cronon, “Kennebec Journey,” in *Under an Open Sky: Rethinking America’s Western Past*, ed. William Cronon et al. (New York: Norton, 1992), 33.

Spaniards were robbing, slaughtering, enslaving and converting them; higher up [along the Atlantic seaboard], the English were trading beads and blankets to them for a consideration, and throwing in civilization and whiskey, 'for lagniappe;' and in Canada the French were schooling them in a rudimentary way, missionarying among them, and drawing whole populations of them at a time to Quebec, and later to Montreal, to buy furs of them. Necessarily, then, these various clusters of whites must have heard of the great river of the far west.³⁶

While the multicultural and often-violent history that Twain presents here is not surprising, his inclusion of it highlights the original cultural interconnectedness of North America. It also makes clear the various populations vying for proprietary control of spaces and thus the power to establish boundaries and to assign identity to places for a time.³⁷ Of course, such a dynamic view of human geography, wherein borders and boundaries shift as a result of historical conflict, is made even clearer in the aftermath of the Civil War.

The volatility of Twain's river both reflects and exacerbates the instability of geopolitical boundaries. Writing about the river and Twain's construction of "meaning" in *Life on the Mississippi*, T.S. McMillin suggests that Twain creates an interplay "between the natural history of the river (physical facts) and its social history (facts from 'historical history') [that] requires the kind of perspective that comes from conceptual overlook."³⁸ That "conceptual overlook," I suggest, is profoundly geographic, and Twain's viewing the river against a backdrop of human society emphasizes the continual transformation of geographic place. In one comedic passage, for example, Twain notes that, given the river's tendency to shorten itself through cutoffs, "any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of aldermen."³⁹ Although obviously humorous, Twain's underlying perspective is not to be dismissed. It captures in tongue-in-cheek fashion the shifting nature of the land, the potential fluidity of socio-political borders, the ever-changing positions—

³⁶ Ibid. 43.

³⁷ David Harvey, *Justice, Nature and the Geography of Difference* (Malden, MA: Blackwell, 1996), 261.

³⁸ T.S. McMillin, *The Meaning of Rivers: Flow and Reflection in American Literature* (Iowa City: U of Iowa P, 2011), 7.

³⁹ Twain, *Life on the Mississippi* 147.

through fusion, fissure, or other means—of human places. If historian Arif Dirlik is correct that “place is the location [...] where the social and the natural meet,” then Twain’s formulations of “place” are in constant flux⁴⁰—and ultimately subvert Dirlik’s own formulation. Whereas Dirlik asserts that the physical world lends fixity to historical place, Twain perceives neither the natural nor the social world as timeless and fixed. Both are instead dynamic and even turbulent.

Apart from humor, Twain highlights in various contexts the interplay between the natural history of the river (its changing physical facts) and its social history (its changing historical facts or roles). Indeed, this is a division that Twain himself gestures toward in the opening pages of *Life on the Mississippi* (“Let us drop the Mississippi’s physical history, and say a word about its historical history—so to speak”).⁴¹ Using an example that proves especially pertinent in the aftermath of the Civil War, Twain notes:

A cut-off plays havoc with boundary lines and jurisdictions; for instance, a man living in the State of Mississippi to-day, a cut-off occurs to-night, and to-morrow the man finds himself and his land over on the other side of the river, within the boundaries and subject to the laws of the State of Louisiana! Such a thing, happening in the upper river in the old times, could have transferred a slave from Missouri to Illinois and made a free man of him.⁴²

Twain would concur with Doreen Massey’s definition of place as an abstraction “woven together out of ongoing stories, as a moment within power-geometries, as a particular [and temporary] constellation within the wider topographies of space.”⁴³ Twain’s Mississippi is constantly transforming its own boundaries, banks, and landscape; its physical nature is obviously fluid, not fixed. Twain’s river also plays with and transforms social history, figuratively carving its way through multiple borders while literally challenging the stability of jurisdiction, of human place. In short, Twain creates the Mississippi as a challenge to the definition and enforcement of the borders or boundaries of “moment[s]

⁴⁰ Arif Dirlik, “Place-based Imagination: Globalism and the Politics of Place,” in *Places and Politics in an Age of Globalization*, R. Prazniak et al. (Lanham MA: Rowman and Littlefield, 2011), 15-51.

⁴¹ Twain, *Life on the Mississippi* 41.

⁴² *Ibid.* 40.

⁴³ Massey, *For Space* 133.

within power-geometries"⁴⁴—all of which are apt to change. Writing elsewhere of the Mississippi, Twain notes, "In this region the river passes from Kentucky into Tennessee, back into Missouri, then back into Kentucky, and thence into Tennessee again. So a mile or two of Missouri sticks into Tennessee."⁴⁵ Here, jurisdictional and political boundaries are blurred and perhaps even made arbitrary by the river—despite the fact that, "in the old times," a slave certainly would have cared about which side of the river he or she occupied.

The river's role in the dialectical interplay between the physical and social is highlighted by Twain's description of Vicksburg's political and economic plight during the Civil War. During the North's bombardment of the city, residents burrowed into the banks of the river for shelter. "The [caves] were mere holes," Twain writes, "tunnels, driven into the perpendicular clay bank, [which] then branched Y shape, within the hill."⁴⁶ With power-relation struggles temporarily abandoned, some 3,000 residents ("merely the population of a village," Twain wryly remarks) were equalized as underground cave-dwellers in a striking image of contingency of place. The caves themselves comprised an intimate nexus between human place on the one hand and the physical space of the river on the other—an interplay of the physical and social that reshaped Vicksburg itself.⁴⁷ Indeed, as Twain, emphasizes, the river physically resituated "the lofty hill-city, Vicksburg," during the course of the war. "A cut-off has made a country town of it," Twain writes, "like Osceola, St. Genevieve, and several others. There is currentless water—also a big island—in front of Vicksburg now."⁴⁸ In this articulation of postwar Vicksburg, Twain captures a somewhat rare occurrence of what James Donald has referenced as the clear fullness of the contingency of place.⁴⁹

Perhaps the best illustration of Twain's geographic vision comes in his detailed discussion of Napoleon, Arkansas, a discussion operating as a loosely constructed frame narrative that thematically binds together other sections of the text while also serving as a focal case study. In the book's opening chapters, Twain establishes Napoleon as the site of historical as well as global and multicultural interactions: "To the admiration of the savages, La Salle set up a cross with the arms of France on it, and took possession of the whole country for the king." Identifying "the

⁴⁴ Ibid.

⁴⁵ Twain, *Life on the Mississippi* 196.

⁴⁶ Ibid. 257.

⁴⁷ Ibid. 258.

⁴⁸ Ibid. 257.

⁴⁹ James Donald, *Imagining the Modern City* (Minneapolis: U of Minnesota P, 1999), 168.

future town of Napoleon, Arkansas,” as the site of “these performances,” Twain continues:

Marquette’s and Joliet’s voyage of discovery ended at the same spot—the site of the future town of Napoleon. When De Soto took his fleeting glimpse of the river, away back in the dim early days, he took it from that same spot—the site of the future town of Napoleon, Arkansas. Therefore, three out of the four memorable events connected with the discovery and exploration of the mighty river occurred, by accident, in one and the same place. It is a most curious distinction, when one comes to look at it and think about it. France stole that vast country on that spot, the future Napoleon; and by and by Napoleon himself was to give the country back again!—make restitution, not to the owners, but to their white American heirs.⁵⁰

By tying a remarkable set of historical coincidences to a given physical setting, Twain establishes the convergence of far-flung cultures, European and Native American, across time and in one particular place. The convergence is the more striking for Napoleon’s isolation and intense localism. It is hard to imagine a more “local” or rural place, one less hampered by cosmopolitan ties or influences, one less likely to be named “Napoleon.” Yet long before it received its name, the physical location was being contested by an array of cultural forces intent on enacting power geometries. This “local/e” is hardly a closed or rooted phenomenon. On the one hand, Napoleon illustrates “place” as the historical sum of local and global interactions, while on the other, it is the embodied fate of physical place—of geographical mapping, of changing borders, of economic positioning and parceling, of physical “curb appeal.” In this sense, the town undermines notions of place as “authentic” or even as “already divided.”

Twain’s Napoleon is also established within a contemporary web of transnational narratives and, as abstract place, is created as a nexus of cultural and temporal trajectories. In the words of geographer Tim Cresswell, Twain’s Napoleon thus depends upon an understanding of place as an “event rather than a secure ontological thing rooted in notions of the authentic.”⁵¹ In a subsidiary plotline, Twain tells a story about hidden gold, the Civil War, and an array of characters in Germany, himself included, who, at various points in time, have been connected to Napoleon,

⁵⁰ Twain, *Life on the Mississippi* 48.

⁵¹ Tim Cresswell, *Place: A Short Introduction* (Malden, MA: Blackwell, 2004), 40.

Arkansas. Akin to Hannibal, Missouri, Napoleon is just the sort of place that, in Twain's fiction, becomes the quintessential rural American town. Yet in this telling of the story, Napoleon is defined far less by its quaint provinciality than by its connections to farflung people and events. Like the Mississippi itself, it is defined by and becomes a confluence of tributaries, of histories. When we consider that Napoleon is also the place where, in June 1858, Twain first learned of the boiler explosion that sunk the steamboat *Pennsylvania* and fatally injured his brother Henry, the other historical tributaries acquire a deeper ironic significance.

The Napoleon plotline ends when Twain learns that the town has been entirely destroyed by the river. As his steamboat rounds the bend where he expects to see Napoleon, Twain is shocked to discover that "the Arkansas River [had] burst through it [the town], tore it all to rags, and emptied it into the Mississippi!"⁵² The follow-up sentence succinctly captures Twain's lesson of contingency. He writes: "Yes, it was an astonishing thing to see the Mississippi rolling between unpeopled shores and straight over the spot where I used to see a good big self-complacent town twenty years ago[, but it was] a town no more—swallowed up, vanished, gone to feed the fishes; nothing left but a fragment of a shanty and a crumbling brick chimney!"⁵³

Twain's Napoleon, Arkansas, establishes "place" as both *event* and *process*. From Native American "owners" to Marquette, De Soto, and Napoleon himself, and from these French "owners" to their "white American heirs," the destroyed town has repeatedly been transformed as it changed hands. That the town's final owner is the river itself underscores the uncertainty of even the town's physical site, an uncertainty marked by Twain's nostalgic eulogy of the town—his memories of Napoleon's "prettiest" and most promising girl and of its connection to the loss of his brother. This early section of *Life on the Mississippi* introduces an important question that echoes throughout the text: how should one deal with the inherent instability of place?

Twain's Portable Sense of Place

Life on the Mississippi describes Twain's return to the river after nearly twenty years away from it, and, to tally the many changes in the river and its towns, he sets his *present* experiences of the river against his *past* memories of it. Traveling downriver, Twain's first stop is St. Louis, where he laments the absence of riverboat men. "I saw there none of the swell airs and graces, and ostentatious displays of money, and

⁵² Ibid. 247.

⁵³ Ibid. 247.

pompous squanderings of it,” he writes, “which used to distinguish the steamboat crowd from the dry-land crown in the bygone days, in the thronged billiard-rooms of St. Louis.” Sadly, “a glory that once was had dissolved and vanished away in these twenty-one years.”⁵⁴ Twain’s choice of language here, especially his use of “dissolved” and “vanished away,” clearly links the changes wrought on St. Louis with those wrought on the river itself. The Mississippi’s alluvial banks have eroded, and its steamboat crowd and culture have disappeared. Twain writes:

I could recognize big changes from Commerce down. A big island that used to be away out in the mid-river, has retired to the Missouri shore. [...] The island called Jacket Pattern is whittled down to a wedge now, and booked for early destruction. Goose Island is all gone but a little dab the size of a steamboat. [...] One of the islands formerly called the Two Sisters is gone entirely.⁵⁵

Twain recognizes that, in Massey’s words, “what is special about place is not some romance of pre-given collective identity or of the eternity of the hills,”⁵⁶ but instead what geographer David Harvey would call “temporary permanances.” For Harvey, like Twain, “[t]he process of place formation is a process of carving out ‘permanances’ from the flow of processes creating spatio-temporality. But the ‘permanances’—no matter how solid they may seem—are not eternal but always subject to time as ‘perpetual perishing.’”⁵⁷ How, then, does Twain reconcile his *nostalgia for place* with the inevitability of *loss of place*—with his recognition of place as process?

I believe that Twain finds answers in his early training as a riverboat pilot. Early in his training, Twain is told by his mentor, Mr. Bixby, that the value of the Mississippi lies in its changeability. Finding the details of the ever-changing river practically impossible to learn, Twain struggles to understand Bixby’s assertion, declaring,

No prominent hill would stick to its shape long enough [...] but it was all dissolving and changeful as if it had been a mountain of butter in the hottest corner of the tropics [...]. [Yet Bixby]

⁵⁴ Ibid. 169.

⁵⁵ Ibid. 190.

⁵⁶ Massey, *For Space* 140.

⁵⁷ Harvey 261.

said,--“That’s the virtue of the thing. If the shapes did n’t change every three seconds they would n’t be of any use.”⁵⁸

One can hardly imagine a more fluid, metamorphic sense of place than what Twain presents here. While certainly difficult to navigate, Bixby’s Mississippi is magically and mythically transformative—to the end that Bixby locates the river’s virtue and value in just this transformative condition. So what is Bixby’s lesson? Place as open and changeable is vital, useful, interesting, and politically promising; place as fixed and unchanging is none of these things. An open place has an open future, untainted by fixed allegory; to an extent, at least, it may also have a more open past. It is thus no mystery why Twain’s sense of place—conveniently misunderstood and misapplied—appealed to a late nineteenth-century nation with imperialist ambitions.

While Twain seems to appreciate the politics of the open place, his final perspectives of place are not so simple. Instead, he combines openness with the capacity for what might be called a portable sense of place—a place perception that retains personal distinctiveness and rootedness and that is shielded somewhat from the inevitable change and dissolution to which a given place is subject. Twain’s Hannibal, for instance, is both rich and timeless. This is also a lesson Twain learns from Bixby, as stated earlier: “There’s only one way to be a pilot, and that is to get this entire river by heart. You have to know it just like A B C.”⁵⁹ But the novice pilot Twain must also learn the *shape* of the river. Bixby declares, “My boy, you’ve got to know the shape of the river perfectly. It is all there is left to steer by on a very dark night. Everything else if blotted out and gone. But mind you, it has n’t the same shape in the night that it has in the day-time.”⁶⁰ Bixby likens this knowledge of the river to learning the shape and feel of the hallways in one’s own home. “How do you follow a hall at home in the dark?” Bixby asks. “Because you know the shape of it. You can’t see it.”⁶¹

Bixby’s claim that this shape is “all there is left to steer by on a very dark night” suggests the possible melancholy that attends the loss of place. But it also suggests that such “shape knowledge” is akin to memory itself. Even though Napoleon is “blotted out and gone,” Twain the writer still retains his knowledge of its shape, its overall look and feel, its remembered reality. As Bixby insists, “[Y]ou only learn the shape of the river; and you learn it with such absolute certainty that you

⁵⁸ Twain, *Life on the Mississippi* 89.

⁵⁹ Ibid. 76.

⁶⁰ Ibid. 85.

⁶¹ Ibid.

can always steer by the shape that's in your head, and never mind the one that's before your eyes."⁶²

This is no doubt the task of the writer as well as of the pilot. Bixby's comparison of learning the river to learning the alphabet connects his lesson to language and writing: intense practice and a potent memory are necessary to pilot and writer alike. Twain must know the shape and character of the river or of Napoleon or Hannibal even when the place has inevitably and forever changed in shape and form. In the end, perhaps this is the best way to *preserve* place, much less to *know* it: to carry its vitality and significance as indelible memory.

⁶² Ibid. 86.

Probing Particle-Wave Duality with the Stern-Gerlach Effect

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Abstract

A core tenet of quantum theory is the fact that objects can behave as particles, waves, or a combination of both. This principle is known as particle-wave duality. Quantum objects will exhibit different degrees of particle or wave behavior depending on how their observables are entangled. An illustrative example of entanglement is the Stern-Gerlach effect, which entangles the spin of objects with their trajectory. A single Stern-Gerlach magnetic field will cause the objects to behave as particles, but a second field with its inhomogeneity oriented in a different direction to the first will cause the objects to recover some wave behavior. This is evidenced in a pattern of fringes in each object's spatial probability density. Maximum entanglement leads to pure particle behavior while the absence of entanglement leads to pure wave behavior. The amount of entanglement can be controlled by choosing the angle between the inhomogeneities of the two fields that act on the object. Having the two field inhomogeneities oriented perpendicularly to each other leads to maximum recovered wave behavior for spin-1/2 objects. The amount of recovered wave behavior decreases as the field inhomogeneity directions move towards being parallel.

Introduction

The principle of particle–wave duality is a defining characteristic of quantum theory. Classical theories treat localized massive objects (e.g., cannonballs, electrons) as particles and extended oscillations (e.g., ocean swells, light) as waves. Although it may seem that an object cannot be both a particle and a wave, several famous experiments have indicated that this is the case. For example, the photoelectric effect demonstrates that light can behave as a stream of particles,¹ and electron microscopy shows that electrons can behave as waves.² Whether a quantum object exhibits wave or particle properties depends on the conditions of the experiment; however, these quantum objects do not always behave strictly as waves or strictly as particles; they can exhibit both wave and particle properties simultaneously. The two properties follow a duality relation: the more a quantum object behaves like a wave, the less it behaves like a particle, and vice versa. Bohr expressed this relation in 1928 by stating that wave and particle behaviors are “complementary”³ to each other.

The degree to which a quantum object exhibits particle or wave behavior depends on how its observables are entangled. Entanglements are formed through physical interactions between observables that cause them to become correlated with each other. For example, consider the double-slit experiments shown in Figure 1. In both experiments, quantum objects propagate to the right from a source, encounter a mask with two slits, and then strike a detector screen.

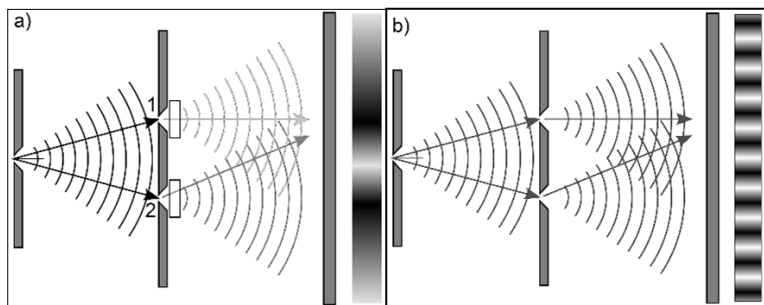


Figure 6. Two double-slit experiments. In experiment a), detectors are placed on the slits. There are two regions where the objects are detected on the screen and no fringes appear. In experiment b), there are no path detectors on the slits. Fringes appear on the detector screen.

Placing a path detector on each slit, as in Figure 1a, causes the path of the quantum object to become entangled with the detectors. Let $|p_1\rangle$ and $|p_2\rangle$ be the path states and let $|d_1\rangle$ and $|d_2\rangle$ be the detector states. The

state of the system consisting of the detectors and an object that passes through the mask is then in the superposition state

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|p_1\rangle|d_1\rangle + |p_2\rangle|d_2\rangle). \quad (1)$$

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|p_1\rangle + |p_2\rangle). \quad (2)$$

This indicates that the detector state is completely entangled with the path state of the quantum object. That is, the object will have taken path 1 if and only if the detector state is $|d_1\rangle$, and the object will have taken path 2 if and only if the detector state is $|d_2\rangle$. The presence of the detectors causes the quantum object to behave as a particle; it can only pass through a single slit. If the detectors are removed, as in Figure 1b, the state of the object is

In this situation, the object behaves as a wave that passes through both slits simultaneously, giving rise to a fringe pattern on the detector screen.

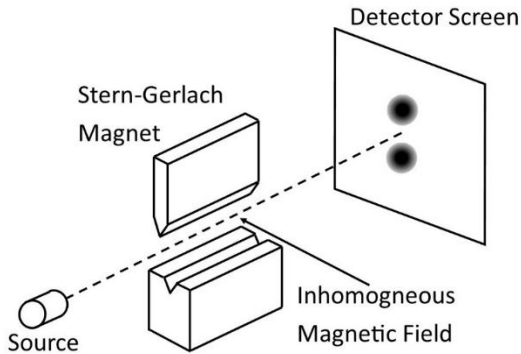


Figure 7. The Stern-Gerlach effect entangles the position of a quantum object with its spin. For a spin-1/2 object, this causes a single beam of quantum objects to split into two distinct beams

A similar entanglement occurs in a Stern-Gerlach experiment.⁴ The Stern-Gerlach effect, as depicted in Figure 2, splits a beam of spin-1/2 quantum objects into two distinct beams.⁵ The inhomogeneous magnetic field that the objects pass through entangles the spin of the atoms with their trajectory. Objects deflected upward are spin-up and objects deflected downward are spin-down. There are only two regions where the objects strike the detector screen. Not only does this show that spin is quantized, it demonstrates that the objects are behaving as particles since

no interference fringes appear on the screen no matter how close the two regions on the screen become.

Although the experimental setup shown in Figure 2 forces quantum objects to exhibit particle behavior, the possibility remains to recover their wave behavior after they pass through the magnetic field but before they strike the detector screen. An experimental set-up to accomplish this was envisioned by Qureshi and Rahman⁶ and is depicted in Figure 3. In this manner, the Stern-Gerlach effect can be used to create a quantum eraser.⁷ The which-way magnet entangles the position of the quantum objects with their spin in the z -dimension by Stern-Gerlach separation. A second magnet called the eraser magnet then does the same but in the x -dimension. Since the spin in the x -dimension is independent of the spin in the z -dimension, this second entanglement erases the first. This is evidenced in the fringe pattern that appears on the detector screen. Because of the erasure and separation caused by the eraser magnet, the beams exiting the which-way magnet interfere in the z -direction.

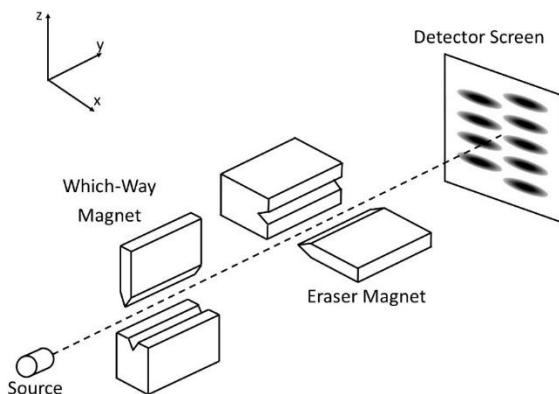


Figure 8. Example of a quantum eraser setup using the Stern-Gerlach effect. Each magnet entangles spin with position for each object that passes through them. Since the magnets are oriented perpendicularly, the second magnet erases the entanglement caused by the first.

Methods

This section describes the methods used to find the time evolution of the wavefunction of an object in an experiment such as that shown in Figure 3. The results of this method are presented in the following section through plots of the spatial probability density of each object.

Spin Eigenstates

In the Stern-Gerlach system, the position of the object becomes entangled with its spin. In the case of a spin-1/2 object, an initial single beam with undetermined spin will split into two beams, as seen in Figure 2. The spin eigenstates in the z-direction are labeled as $|s, m_s\rangle_z$, where s is the spin value of the quantum object and m_s is the spin quantum number. Objects in the upper beam are spin up and are in the spin state $|\frac{1}{2}, \frac{1}{2}\rangle_z$ and the position state $|\psi_{1/2}\rangle_z$. Objects in the lower beam are spin down and are in the spin state $|\frac{1}{2}, -\frac{1}{2}\rangle_z$ and the position state $|\psi_{-1/2}\rangle_z$. The state of an object that is not known through observation to be in either beam is in the superposition state

$$|\Psi\rangle = \frac{1}{\sqrt{2}} \left(\left| \frac{1}{2}, \frac{1}{2} \right\rangle_z |\psi_{1/2}\rangle_z + \left| \frac{1}{2}, -\frac{1}{2} \right\rangle_z |\psi_{-1/2}\rangle_z \right). \quad (3)$$

This state has the same structure as the state in Eq. (1), indicating particle behavior.

The state in Eq. (3) is written in terms of the spin eigenstates in the z-direction, which is the direction of the first magnetic field's inhomogeneity. When the second field acts on the object, the inhomogeneity will be in a different direction. To express the new state of the object, the spin eigenstates $|s, m_s\rangle_z$ must be written in terms of the spin eigenstates in the new field inhomogeneity direction. This can be done for any angle and for any spin value.⁸ For example, if the second field is in the x-direction, then

$$\left| \frac{1}{2}, \frac{1}{2} \right\rangle_z = \frac{1}{\sqrt{2}} \left(\left| \frac{1}{2}, \frac{1}{2} \right\rangle_x - \left| \frac{1}{2}, -\frac{1}{2} \right\rangle_x \right) \text{ and } \left| \frac{1}{2}, -\frac{1}{2} \right\rangle_z = \frac{1}{\sqrt{2}} \left(\left| \frac{1}{2}, \frac{1}{2} \right\rangle_x + \left| \frac{1}{2}, -\frac{1}{2} \right\rangle_x \right).$$

Inserting these into Eq. (3) yields

$$|\Psi\rangle = \frac{1}{2} \left[\left(|\psi_{1/2}\rangle_z + |\psi_{-1/2}\rangle_z \right) \left| \frac{1}{2}, \frac{1}{2} \right\rangle_x + \left(-|\psi_{1/2}\rangle_z + |\psi_{-1/2}\rangle_z \right) \left| \frac{1}{2}, -\frac{1}{2} \right\rangle_x \right], \quad (4)$$

which has the same structure as the state in Eq. (2). Each spin state is now associated with both position states. If enough time elapses for Stern-Gerlach separation to occur in the x-dimension, the object will behave as a wave and exhibit self-interference.

Propagating Wavepackets

The Hamiltonian that describes the evolution of a quantum object in a magnetic field is

$$H = \frac{p^2}{2m} - \boldsymbol{\mu} \cdot \mathbf{B}, \quad (5)$$

where p is the momentum of the object, m is its mass, $\boldsymbol{\mu}$ is its magnetic moment, and $\mathbf{B}$ is the magnetic field. The magnetic field from a Stern-Gerlach magnet can be approximated as a linearly inhomogeneous field. Assuming the inhomogeneity of the field is in the x -dimension gives $\boldsymbol{\mu} \cdot \mathbf{B} = \beta \sigma_x x$, where β is the constant describing the magnitude of the inhomogeneity of the field and σ_x is the Pauli spin operator for the spin in the x -dimension. The Stern-Gerlach Hamiltonian can now be written as

$$H = \frac{p_x^2}{2m} - \beta \sigma_x x. \quad (6)$$

The problem at hand is to use this Hamiltonian to determine how the wavefunction of an object in a Stern-Gerlach field will evolve over time according to the Schrödinger equation. If each quantum object in the beam has a Gaussian profile perpendicular to the beam before it encounters the first Stern-Gerlach field, a simple method given by Tannor⁹ can be used. Given a normalized initial wavefunction of the form

$$\Psi(x, 0) = \left(\frac{2\alpha_{0,x}}{\pi}\right)^{1/4} \exp\left[-\alpha_{0,x}(x - x_0)^2 + \frac{i}{\hbar}p_{0,x}(x - x_0) + \frac{i}{\hbar}\gamma_{0,x}\right], \quad (7)$$

it can be assumed that the wavefunction at a later time will have the form

$$\Psi(x, t) = \left(\frac{2\alpha_{t,x}}{\pi}\right)^{1/4} \exp\left[-\alpha_{t,x}(x - x_t)^2 + \frac{i}{\hbar}p_{t,x}(x - x_t) + \frac{i}{\hbar}\gamma_{t,x}\right], \quad (8)$$

where $\alpha_{t,x}$, x_t , $p_{t,x}$, $\gamma_{t,x}$ are functions of t . Writing the wavefunction in this form makes it simple to determine the average momentum ($p_{t,x}$) and position (x_t) of the wavepacket. The width of the wavepacket is described by $\alpha_{t,x}$ and $\gamma_{t,x}$ is a phase factor.

The parameters $\alpha_{t,x}$, x_t , $p_{t,x}$, $\gamma_{t,x}$ can be solved for by inserting Eq. (8) into the Schrödinger equation: $i\hbar \frac{\partial}{\partial t} \Psi = H\Psi$. By equating like powers of x , a set of coupled differential equations is found:

$$\begin{aligned} \dot{\alpha}_{t,x} &= -\frac{2i\hbar}{m} \alpha_{t,x} \\ \dot{p}_{t,x} &= \beta \sigma_x \\ \dot{x}_t &= \frac{p_{t,x}}{m} \\ \dot{\gamma}_{t,x} &= p_{t,x} \dot{x}_t - \frac{p_{t,x}^2}{2m} - \frac{\hbar^2}{m} \alpha_{t,x} + \beta \sigma_x x_t. \end{aligned} \quad (9)$$

The solution to these equations is

$$\alpha_{t,x} = \frac{\alpha_{0,x}}{1 + \frac{2i\hbar t \alpha_{0,x}}{m}}$$

$$\begin{aligned}
p_{t,x} &= \beta \sigma_x t + p_{0,x} \\
x_t &= \frac{1}{m} \left(\frac{1}{2} \beta \sigma_x t^2 + p_{0,x} t \right) + x_0 \\
\gamma_{t,x} &= \frac{i\hbar}{2} \ln \left(1 + \frac{2i\hbar t \alpha_{0,x}}{m} \right) + \frac{p_{0,x}^2}{2m} t + \frac{1}{3m} \beta^2 t^3 \\
&\quad + \beta \sigma_x \left(\frac{p_{0,x}}{m} t^2 + x_0 t \right) + \gamma_{0,x}.
\end{aligned} \tag{10}$$

With these expressions, Eq. (8) can be used to describe the one-dimensional wavefunction over time.

The wavefunction in two dimensions can be described by a product of two one-dimensional wavefunctions:

$$\Psi(x, z, t) = \Psi_x(x, t) \Psi_z(z, t). \tag{11}$$

Let ϕ be the angle between the inhomogeneity direction of the Stern-Gerlach field and the positive xx -axis and σ_ϕ be the spin operator in the direction of the inhomogeneity. The Hamiltonian describing the evolution of the quantum object is

$$\begin{aligned}
H &= \frac{p^2}{2m} - \beta \sigma_\phi (\cos \phi x + \sin \phi \sigma_\phi z) \\
&= H^{(x)} + H^{(z)}
\end{aligned} \tag{12}$$

where $H^{(x)} = \frac{p_x^2}{2m} - \beta \cos \phi \sigma_\phi x$ and $H^{(z)} = \frac{p_z^2}{2m} - \beta \sin \phi \sigma_\phi z$.

Having $H^{(x)}$ act on Eq. (7) yields $\Psi_x(x, t)$ and having $H^{(z)}$ act on the initial normalized wavefunction

$$\Psi(z, 0) = \left(\frac{2\alpha_{0,z}}{\pi} \right)^{1/4} \exp \left[-\alpha_{0,z}(z - z_0)^2 + \frac{i}{\hbar} p_{0,z}(z - z_0) + \frac{i}{\hbar} \gamma_{0,z} \right] \tag{13}$$

yields $\Psi_z(z, t)$. Inserting $\Psi_x(x, t)$ and $\Psi_z(z, t)$ in Eq. (11) then gives a description of the two-dimensional wavefunction while it is being acted on by the Stern-Gerlach field. This procedure may be repeated for each field that acts on the object to find the wavefunction at all times.

Results and Discussion

The methods described above are used to determine how the wavefunction of a quantum object evolves over time as it experiences Stern-Gerlach fields, each with its inhomogeneity in a different direction. Wave behavior can be identified by fringes in plots of the spatial probability density $|\Psi(x, z, t)|^2$. All plots in Figures 4 and 5 are stills taken from animations created to visualize how the probability density evolves

in time. For simplicity, the initial wavefunction is taken to be a Gaussian wavepacket centered at the origin with no average momentum. The probability density for such a wavefunction is shown in Figure 4a. Figure 4b shows the probability density after the first Stern-Gerlach field has been acting on the object for a time.

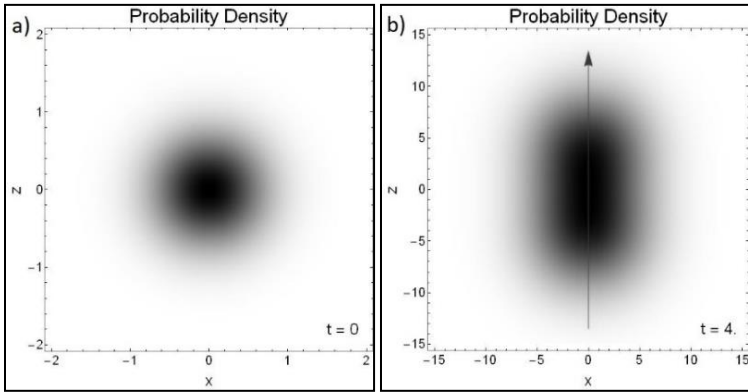


Figure 9. a) shows the initial spatial probability density of a Gaussian wavepacket centered at the origin with no momentum on average. b) shows how the probability density has evolved after the object has been acted on by a Stern-Gerlach field with its inhomogeneity in the zz -direction. The arrow shows the direction of the inhomogeneity of the field which has been acting on the object. The parameters have been set to the following values: $\hbar = m = 1, \beta = 1, \alpha_{0,x} = \alpha_{0,z} = 1, p_{0,x} = p_{0,z} = 0, x_0 = z_0 = 0, \gamma_{0,x} = \gamma_{0,z} = 0$

The amount of wave behavior that is recovered when the second field acts on the object depends greatly on the angle between the inhomogeneity directions of the fields. Figure 5a shows the evolution of the probability density for a spin-1/2 object that has the inhomogeneity of the second field at an angle of $\pi/2$ radians to the first. At time $t = 16$ the fringes are very pronounced. In comparison, Figure 5b shows the evolution of the probability distribution when the inhomogeneity of the second field is at an angle $\pi/4$ radians to the first. Fringes still appear in this case and they are oriented in the same direction as those in Figure 5a, but they are much fainter. This indicates that less wave behavior has been recovered than in the case shown in Figure 5a.

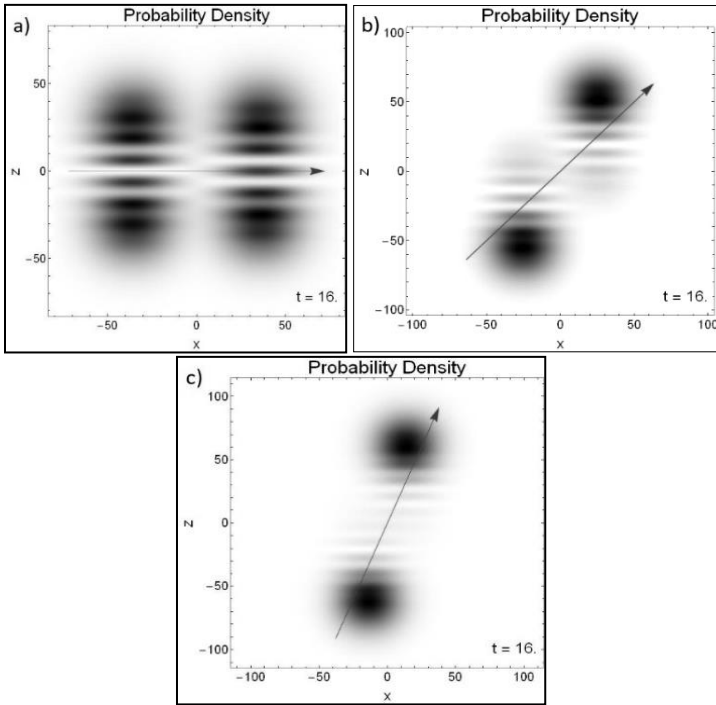


Figure 10. Plots of the spatial probability density for spin-1/2 objects after being acted on by a second Stern-Gerlach field with its inhomogeneity direction at different angles to the first. The angle is $\pi/2$ rad in a), $\pi/4$ rad in b), and $\pi/8$ rad in c). The arrow shows the direction of the inhomogeneity of the field that has been acting on the object. The parameters have been set to the following values: $\hbar = m = 1, \beta = 1, \alpha_{0,x} = \alpha_{0,z} = 1, p_{0,x} = p_{0,z} = 0, x_0 = z_0 = 0, \gamma_{0,x} = \gamma_{0,z} = 0$. The probability density at earlier times is shown in Figure 4.

Figure 5c shows the evolution of the probability density when the angle between the inhomogeneity directions is $\pi/8$ radians. The fringes that appear in this case are even fainter than those shown in Figure 5b. Together, Figure 5a–c indicates that the amount of recovered wave behavior is maximized when the angle between the inhomogeneity directions of the Stern-Gerlach fields is $\pi/2$ radians. The recovered wave behavior decreases as this angle moves to 0 or π radians. This is not surprising because, for the spin-1/2 case, the spin eigenstates in a certain direction are equally weighted superpositions of the spin eigenstates in the orthogonal direction.

Conclusion

An analytic expression has been presented that describes how Gaussian wavepackets evolve under successive Stern-Gerlach splittings in different directions. The parameters of this wavefunction are determined by a set of coupled differential equations, which arise by inserting the wavefunction into the Schrödinger equation. The spatial probability density of the quantum object can then be plotted for all times.

These plots of the spatial probability density show that including a second Stern-Gerlach field with its inhomogeneity at an angle to the first causes fringes to appear. These fringes indicate that the quantum objects in the experiment have recovered some wave behavior. For the spin-1/2 case, the fringes are clearest when the angle between the two field inhomogeneities is $\pi/2$ radians. This is the angle that allows for the greatest degree of wave behavior to be recovered. As the angle moves away from $\pi/2$ radians, the fringes become less distinct, indicating that less wave behavior has been recovered.

The Stern-Gerlach effect has proven to be a useful demonstration of how quantum objects can continuously vary between exhibiting particle behavior and wave behavior. In the context of the experiment shown in Figure 3, the amount of wave behavior each quantum object displays can be controlled by setting the angle of the eraser magnet relative to the which-way magnet while keeping both parallel to the beam. Future work may generalize the results in this paper to quantum objects with different spin values, consider experiments with more than two Stern-Gerlach fields, and quantify the recovered wave behavior.⁸

Acknowledgments

We express thanks to Manuel Berrondo and the members of the Quantum Information and Dynamics research group at Brigham Young University for many enlightening discussions on topics related to this study.

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The Mathematics of Mario Party 10

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Abstract

The Mario Party video game franchise by Nintendo Co., Ltd. has offered a fun, wholesome party game experience for millions of happy gamers since 1998. The newest installment of the series, Mario Party 10 for the Nintendo Wii U, continues in this tradition. These video games play like a board game but with regular mini-games where players battle for coins and hearts. While players can best these mini-games by strategy, skill, timing, and massive button-mashing, victory in these mini-games and the overall board game often comes down to elements of chance, such as dice rolls and card drawing. This paper will analyze effective Mario Party 10 strategies based upon the mathematics of probability and combinatorics for a specific bingo-like mini-game known as Bowser's Bogus Bingo.

1. Introduction

Video games and mathematics share a curious relationship. The virtual geometries, physics, and laws manufactured by game designers can create strange, new worlds that can become playgrounds for mathematical discovery. For example, in the classic 1979 game *Asteroids* by

Atari, Inc., gamers play on a torus (the shape of a doughnut) because of the wrap-around feature of the rectangular screen. Also, if players are aware of the mathematics, then it might influence them to play using more optimal strategies.

In his book, *Power-Up: Unlocking the Hidden Mathematics in Video Games*, Matthew Lane (Lane, 2017) explores many other hidden mathematical gems in video games. Other recent examples of the intersection between video games and higher mathematics include (Aloups, Demaine, Guo, & Viglietta, 2015), (Broussard & Malandro, 2016), (De Biasi & Ophelders, 2016), (Demaine, Viglietta, & Williams, 2016), and (Misra, 2016).

The game *Mario Party 10* was released by Nintendo Co., Ltd., for its Nintendo Wii U console. Like many of its predecessors in the *Mario Party* franchise, *Mario Party 10* consists of four players choosing avatars from characters in the broader *Mario Bros.* franchise (also owned by Nintendo) and playing competitively on a digital board. The players roll dice to progress forward, collecting rewards, such as stars and coins, and activating special events. Spread throughout the game are various mini-games, small games inside the game in which players compete for rewards. The board game design of *Mario Party* lends itself to many mathematical questions about probability, as dice rolls and chance are an important component to this game.

An exhaustive attempt to discuss all the probabilities of *Mario Party 10* will not be included here, although there are certainly many that could be explained. Instead, in this paper, we will discuss a specific mini-game in *Mario Party 10*, called *Bowser's Bogus Bingo* (see Figure 1.1). The character *Bowser* is the antagonist of the *Mario* franchise, and in *Mario Party 10*, a fifth player may play as *Bowser*, whose goal is to extinguish all the lives of the four players in *Team Mario* before they reach the end of the board. Each player on *Team Mario* starts the game with six lives, and every time *Bowser* catches *Team Mario*, a *Bowser Party* mini-game is activated where *Bowser* attempts to take away the lives of the other players according to the mechanics of the various game rules. *Bowser's Bogus Bingo* is one of these mini-games. At the start of this mini-game, the four *Team Mario* players (who we will refer to individually as simple *Mario*) will choose one of six bingo boards on a first-come, first-serve basis. Each bingo board is a 3×3 square consisting of nine smaller square tiles decorated by one of *Bowser's* minions. Each bingo board contains 2–5 different minions. After the selections have been made, *Bowser* will then proceed to roll a six-sided die whose faces consist of six different minions and are the same six minions illustrated across all the bingo boards. *Bowser* then rolls the die five times, with possible repetition. Like traditional bingo, every time a minion is rolled



Figure 1.1: Screenshot of Bowser's Bogus Bingo (NintendoMovies, 2016).

that is present on *Mario's* bingo board, that minion on the board is marked or daubed. A bingo occurs when an entire column, row, or diagonal of *Mario's* bingo board is marked. The mini-game ends after the five rolls, not when the first bingo is obtained. Instead, bingos are cumulative, and at the end of the mini-game *Mario* loses a life for each bingo obtained, cinematically displayed by *Bowser* blasting him with animated fireballs. For any readers who are interested in seeing this mini-game played out, please view the YouTube video (NintendoMovies, 2016) listed in the references.

1.1. Example

Figure 1.2 displays six examples of *Bowser's Bogus Bingo* boards that the *Team Mario* players would choose among. The players only have 10 seconds to select their choice before it is randomly selected for them. As such, players will need to already be prepared with the strategies explained in this paper to make an optimal selection. Also, the boards are selected on a first-come, first-serve basis, meaning the fastest choosing player will be the first to get their board, the second fastest player will get their first or second choice (based upon the fastest player), etc. This method of selection does seem odd for *Team Mario* as they work cooperatively and would be better served deciding among themselves which player should get which board to optimize the expected survival of the game. But as *Bowser's* goal is to destroy *Team Mario* it does seem fitting that he would make the selection process seem competitive when it really ought not to be.

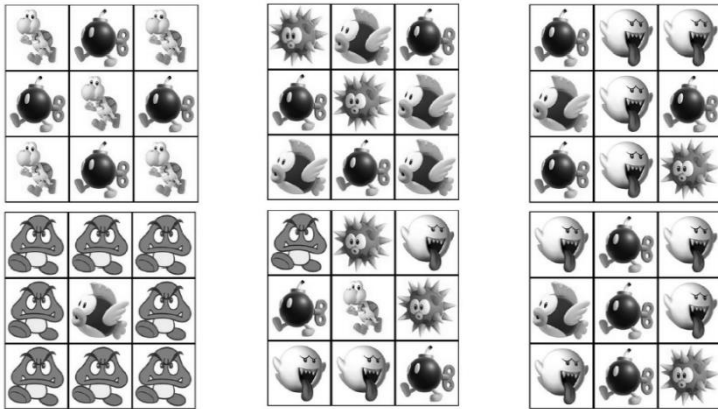


Figure 1.2: Example of bingo boards (ecsaul23, 2016, CC-NC-SA 2.5 license).

As *Bowser's* only action in this mini-game is to roll a die five times, the actions made by *Bowser* are determined by chance and all outcomes are equally likely. As the only action available to *Mario* is to select a board, he should select his board based upon its expected outcome. Because of the purely combinatorial nature of this mini-game, this paper will answer the following question about *Bowser's Bogus Bingo*: what is the best board to select among the six boards available? Section 2 addresses what makes two bingo boards equivalent and thus what details about the board can be ignored by *Mario*. Section 3 addresses the probabilities involved in the bingo game in regard to the dice rolls. Section 4 uses the probabilities of the previous section as well as expected value to provide a formula (Equation 4.2) for *Mario* to determine the protection against bingos of a given board. Finally, Section 5 explains an alternative strategy for *Mario* if he only has a few lives left. Of course, all of these strategies are completely probabilistic and cannot guarantee any outcome of the mini-game, but if *Mario* follows these strategies he will better protect himself from loss of lives, thus maximizing his team's chances of winning the game at large.

2. Equivalence of Bingo Boards

Before we can begin considering the strengths of specific bingo boards, it is important to establish what makes two bingo boards actually different and thus determine what is important about a specific bingo board.

2.1. Example

For example, consider the two bingo boards displayed in Figure 2.1. Despite the boards having distinct characters, the specific characters on the boards are irrelevant in the probability of getting bingos, as any character coming up in a dice roll is equally likely. Only their distinctions matter. Both boards have the property that all tiles around the perimeter have the same character and the character in the center tile is distinct from the other eight tiles. Thus, in considering possible bingo boards, we do not want to distinguish between these two boards as they are equivalent for *Mario*.

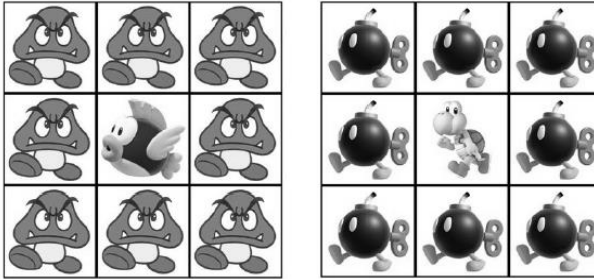


Figure 2.1: Two equivalent bingo boards up to relabeling (ecsaul23, 2016, CC-NC-SA 2.5 license).

Instead of considering bingo boards with characters from *Mario Bros.*, we will instead label each square of a bingo board by a color. As no board can have more than five distinct colors, we label using the colors $\{1, 2, 3, 4, 5\}$.

2.2. Example

This abstract rendering can be applied to the bingo boards already presented in Examples 1.1 and 2.1. The abstracted version of the board from Figure 2.1 is displayed in Figure 2.2. Additionally, the six bingo boards from Figure 1.2 are abstracted in Figure 2.3.

1	1	1
1	2	1
1	1	1

Figure 2.2: Abstracted bingo board from Figure 2.1.

1	2	1
2	1	2
1	2	1

1	2	3
3	1	2
2	3	2

2	1	1
3	1	2
2	1	4

1	1	1
1	2	1
1	1	1

4	2	1
3	5	2
1	1	3

2	1	2
3	1	2
2	1	4

Figure 2.3: Abstracted bingo boards from Figure 1.2.

In abstract algebra, a group¹ is the set of all symmetries of an object, that is, all those functions from an object back into itself that preserve the inherent structure of the object. We say that a group G acts on a set of objects X if each element of the group G maps each object in X onto an object in X . For example, the group S_5 acts on the set of boards of at most five colors, where S_5 denotes the set of all permutations of the list $\{1,2,3,4,5\}$ and every permutation σ in S_5 acts on a bingo board by replacing each number n on the board with the n th number in the permuted list σ .

2.3. Example

For example, consider the permutation $\sigma = (1,2,3,4,5)$, which transforms 1 into 2, 2 into 3, 3 into 4, 4 into 5, and 5 into 1. The bingo boards from Figure 2.3 are then able to be acted upon by σ , whose transformation is illustrated in Figure 2.4.

2	3	2
3	2	3
2	3	2

2	3	4
4	2	3
3	4	3

3	2	2
4	2	3
3	2	5

2	2	2
2	3	2
2	2	2

5	3	2
4	1	3
2	2	4

3	2	3
4	2	3
3	2	5

Figure 2.4: Bingo boards from Figure 2.3 transformed by τ from Example 2.3.

¹ The interested reader can learn more about groups and group actions by reading any introductory textbook to abstract algebra, such as Judson, 2018.

Consider now the permutation $\tau = (1,4,2)(3,5)$, which transforms 1 into 4, 2 into 1, 3 into 5, 4 into 2, and 5 into 3. The bingo boards from Figure 2.3 are then able to be acted upon by τ , whose transformation is illustrated in Figure 2.5.

4	1	4
1	4	1
4	1	4

4	1	5
5	4	1
1	5	1

1	4	4
5	4	1
1	4	2

4	4	4
4	1	4
4	4	4

2	1	4
5	3	1
4	4	5

1	4	1
5	4	1
1	4	2

Figure 2.5: Bingo boards from Figure 2.3 transformed by σ from Example 2.3.

2.4. Example

Ignoring the distinct characters and considering only distinction of colors still does not capture what it means for two boards to be really the same for *Mario*. Consider the two boards illustrated in Figure 2.6. If the boards are abstracted, then the first board will have three colors, say $\{1,2,3\}$, corresponding to rows one, two, and three. Likewise, the second board can be abstracted having three colors, again say $\{1,2,3\}$, which correspond to columns one, two, and three, as in Figure 2.7. In terms of labeling, even if we had labeled the two boards differently, there is no way they can be labeled exactly the same way, but if the first board is rotated counterclockwise by 90° then we see that the two boards are now the same. As rotating a bingo board does not change the probability of getting bingos or the number of bingos obtained in a game, these two boards should be considered equivalent.

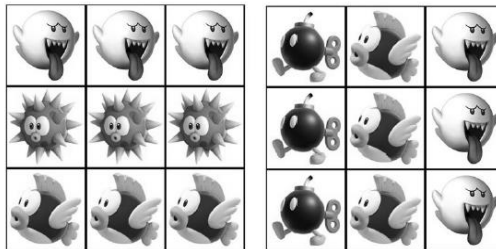


Figure 2.6: Two equivalent bingo boards up to rotation (ecsaul23, 2016, CC-NC-SA 2.5 license).

1	1	1	1	2	3
2	2	2	1	2	3
3	3	3	1	2	3

Figure 2.7: Abstracted bingo boards from Figure 2.6.

In fact, any bingo boards constructed from another using symmetries of the square will have the same probabilities of bingo as the original. There are eight symmetries of a square, namely: the identity (rotate by 0°), rotation (counterclockwise) by 90° , rotation by 180° , rotation by 270° , reflection across the horizontal line of symmetry, reflection across the diagonal line of symmetry containing the top right and bottom left corners, reflection across the vertical line of symmetry, and reflection across the diagonal line of symmetry containing the top left and bottom right corners. The set of these eight symmetries of the square is called the dihedral group D_4 , which acts on each bingo board by performing the associated rotation or reflection.

We say that two bingo boards are *equivalent* if the two boards can be made equal after relabeling colors and applying symmetries to the board. The boards in Figure 2.1 are equivalent as they are equal after relabeling, and the boards in Figure 2.7 are equivalent after relabeling and symmetry, that is, rotational symmetry. For *Mario*, all equivalent boards will have the same probability of success and any choice between equivalent boards is irrelevant in terms of that success.

3. Probabilities of Bingo Boards

In this section, we will compute the probabilities of rolling specific colors on *Mario's* bingo board. Although each board has at most five distinct colors, recall that the die rolled contains six distinct colors. Each roll of the die is an independent random experiment and has six equally likely outcomes. The number of bingos obtained by *Mario* will be determined solely by the number of distinct colors rolled on the die that occur on his board and the positions of those colors on the board. So, to begin, we will consider the probability that the die rolls exactly r colors on *Mario's* board that contains exactly n distinct colors. Clearly, $0 \leq r \leq n$ and $2 \leq n \leq 6$.

Let $\mathbf{P}(E)$ denote the probability² of an event occurring, where E denotes some set of possible outcomes of rolling a 6-sided die five times. Because all outcomes are equally likely and each of the five rolls is independent from the other four, we see that $\mathcal{P}(E) = \frac{|E|}{6^5}$, where $|E|$ denotes the *cardinality* of E , that is, the number of elements contained in it. The denominator 6^5 occurs since each of the five rolls has six possible outcomes.

Let B be a bingo board with exactly n colors. Let S be a subset of colors chosen from $\{1, 2, \dots, n\}$. Then define E_S^n as the event of rolling all the colors from S at least once and no other color from B . As an illustration, imagine we have a bingo board B with exactly $n = 3$ colors, say $\{1, 2, 3\}$. Then $E_\emptyset^3$ is the event that no color on this board is rolled. Then

$$\mathcal{P}(E_\emptyset^3) = \left(\frac{3}{6}\right)^5$$

since each of the five rolls must be selected randomly from the possibilities $\{4, 5, 6\}$. Notice that the coefficient³ of the fraction is $\binom{0}{0} = 1$, the number of ways of selecting zero elements from an empty set (choose nothing). Next, consider E_1^3 , the event that exactly color 1 is rolled and not colors 2 and 3. Then

$$\mathcal{P}(E_1^3) = \left(\frac{4}{6}\right)^5 - \left(\frac{3}{6}\right)^5$$

since the first term considers the possible rolls from the colors $\{1, 4, 5, 6\}$ and the second term excludes the possibility that color 1 is never rolled, that is, excludes the possibility of $E_\emptyset^3$. Notice that the coefficients of the fractions are $\binom{1}{0} = 1$ and $\binom{1}{1} = 1$, the number of ways of selecting zero elements and one element, respectively, from a set containing one element. Note that the probabilities of E_2^3 and E_3^3 are the same as the probability of E_1^3 by similar reasoning. Next, consider $E_{1,2}^3$, the event that exactly colors 1 and 2 are rolled but not color 3. Then

² The interested reader can learn more about probability, as well as binomial coefficients, the inclusion-exclusion principle, and discrete random variables, by reading any introductory textbook on combinatorics, such as Keller & Trotter, 2017.

³ Recall $\binom{m}{k} = \frac{m!}{(m-k)!k!}$, which counts the number of ways k elements can be chosen from a set of m elements where the order of selection is irrelevant and is called a *binomial coefficient* because of their appearance in the Binomial Theorem.

$$\mathcal{P}(E_{1,2}^3) = \left(\frac{5}{6}\right)^5 - 2\left(\frac{4}{6}\right)^5 + \left(\frac{3}{6}\right)^5$$

since the first term considers possible rolls from the colors $\{1,2,4,5,6\}$, the second term excludes the possibility that color 1 or color 2 is never rolled, and the third term includes the possibility that neither colors 1 or 2 are rolled. Notice that the coefficients of the fractions are

$$\binom{2}{0} = 1, \binom{2}{1} = 2, \text{ and } \binom{2}{2} = 1,$$

the number of ways of selecting zero elements, one element, and two elements, respectively, from a set containing two elements. Similarly, the probabilities of $E_{1,3}^3$ and $E_{2,3}^3$ are equal to the probability of $E_{1,2}^3$. Finally, consider $E_{1,2,3}^3$, the event that exactly colors 1, 2, and 3 are rolled. Then

$$\mathcal{P}(E_{1,2,3}^3) = \left(\frac{6}{6}\right)^5 - 3\left(\frac{5}{6}\right)^5 + 3\left(\frac{4}{6}\right)^5 - \left(\frac{3}{6}\right)^5$$

since the first term considers possible rolls from the colors $\{1,2,3,4,5,6\}$, the second term excludes the possibility that color 1, 2, or 3 is never rolled, the third term includes the possibility that colors 1 and 2, 1 and 3, or 2 and 3 are never rolled, and the fourth term includes the possibility that none of these three colors are rolled. Notice that the coefficients of the fractions are $\binom{3}{0} = 1$, $\binom{3}{1} = 3$, $\binom{3}{2} = 3$, and $\binom{3}{3} = 1$, the number of ways of selecting zero elements, one element, two elements, and three elements, respectively, from a set containing three elements. Generalizing this example, we get a formula for the probability for rolling r specific colors among n colors:

$$\mathcal{P}(E_{1,\dots,r}^n) = \sum_{k=0}^r (-1)^k \binom{r}{k} \left(\frac{(6-n+r)-k}{6} \right)^5.$$

Equation.3.1: Probability of rolling the colors 1, ..., r .

Using Equation 3.1, we compute all the possible probabilities of rolling exactly the colors $\{1, \dots, r\}$ and not the colors $\{1, \dots, r\}$ on a bingo board. The results are summarized in Table 3.1.

Table 3.1: The probabilities (as %) of rolling the colors $1, \dots, r$ and none of the colors $1, \dots, r$						
$\mathcal{P}(E_{1,\dots,r}^n): n \setminus r$	0	1	2	3	4	5
1	40.19	59.81				
2	13.17	27.02	32.79			
3	3.13	10.04	16.98	15.82		
4	0.41	2.71	7.33	9.65	6.17	
5	0.01	0.40	2.31	5.02	4.63	1.54

4. Expected Values and Selection Strategy of Bingo Boards

In this section, we will compute the expected values of various bingo boards and explain how expected value is the principal tool for deciding which bingo board to select. Let X be the random variable that assigns the number of lives lost by *Mario* during a game of *Bowser's Bogus Bingo*. Let $\mathbf{P}(X = x)$ denote the probability that *Mario* will lose x lives during the game. The random variable X will be an integer between 0 and 8 (inclusive), where 0 bingos can be obtained if no colors on the board are rolled (although 0 is still possible if some of the colors are rolled) and 8 bingos are obtained if and only if all colors on the board are rolled, commonly called *blackout*. Notably, 7 is the only integer in this range that is impossible to obtain because of the combination of cumulative bingos.

4.1. Example

Let us consider the bingo board given in Figure 2.2. Referencing the probabilities in Table 3.1, there is a 13.17% chance that the colors on this board will not be rolled and *Mario* will gain no bingos. There is a 27.02% chance that color 1 and not color 2 will be rolled, for which *Mario* will gain four bingos. Likewise, there is a 27.02% chance that color 2 and not color 1 will be rolled, but *Mario* will still gain no bingos with this roll. Finally, there is a 32.79% chance that both colors 1 and 2 will be rolled, which causes *Mario* to gain eight bingos. In summary, $\mathbf{P}(X = 0) = 0.1317 + 0.2702 = 0.4019$, $\mathbf{P}(X = 4) = 0.2702$, and $\mathbf{P}(X = 8) = 0.3279$. All other assignments of X have probability 0.

Example 4.1 demonstrates how one can compute the probabilities of bingos obtained for a specific board. But the question still to be answered for *Mario* is how many bingos would *Mario* expect to obtain using a specific bingo board. The board in Figure 2.2 has a high probability

of obtaining no bingos but also a high probability of blackout. In probability theory, the *expected value* of a random variable X is exactly the answer to this question, the average (mean) assignment of X per experiment if the experiment is repeated indefinitely, and is denoted $E(X)$. Expected value is computed using the following weighted average formula:

$$E(X) = \sum_{x=0}^8 x \mathcal{P}(X = x).$$

Equation 4.1: Expected value of the random variable X counting the number of bingos obtained in a game

Let again n be the number of colors on a board and r the number of colors rolled on a board during a game. Let $x_{i_1, \dots, i_r}$ denote the number of bingos obtained if event $E_{i_1, \dots, i_r}^n$ occurs. As these events are mutually exclusive, they partition the sample space of possible outcomes. Using this partition, the expected value of X can be expressed as:

$$\begin{aligned} E(X) &= \sum_{r=0}^n \left(\sum_{1 \leq i_1 \leq \dots \leq i_r \leq n} x_{i_1, \dots, i_r} \mathcal{P}(E_{i_1, \dots, i_r}^n) \right) \\ &= \sum_{r=0}^n \left(\sum_{1 \leq i_1 \leq \dots \leq i_r \leq n} x_{i_1, \dots, i_r} \mathcal{P}(E_{1, \dots, r}^n) \right) \\ &= \sum_{r=0}^n \left(\sum_{1 \leq i_1 \leq \dots \leq i_r \leq n} x_{i_1, \dots, i_r} \right) \mathcal{P}(E_{1, \dots, r}^n). \end{aligned}$$

Equation 4.2: Expected value of X computed via Table 3.1 and scorecards

The sum $\sum x_{i_1, \dots, i_r}$ is the sum of the number of all possible bingos obtained from r colors being rolled. Equation 4.2 and Table 3.1 make it possible to compute $E(X)$ after all the possible bingo combinations are determined. The tabularization of these bingo combinations with respect to r will be called the bingo board's *scorecard*.

4.2. Example

As in Example 4.1, we determined that zero bingos are obtained when $r = 0$, four bingos when $r = 1$ (which includes both events E_1^2 and E_2^2), and eight bingos when $r = 2$. Thus, the scorecard of the bingo board

from Example 4.1 is given in Figure 4.1. Therefore, the expected value of this board is

$$E(X) = 0(0.1317) + 4(0.2702) + 8(0.3279) = 3.7042.$$

Therefore, if *Mario* were to use this board over and over again in the game, then he would expect to obtain about 3.70 bingos per game.

<i>r</i>	0	1	2
<i>X</i>	0	4	8

Figure 4.1: Scorecard for board in Figure 2.2.

4.3. Example

Figure 4.2 shows a slight alteration, but non-equivalent, to Figure 2.2. Its scorecard is found in Figure 4.3. Thus, we can compute the expected value of this board as $E(X) = 4.2446$, which is dramatically worse than the board in Figure 2.2 as computed in Example 4.2. This illustrates that, first, two boards with the same number of colors can have very different expectations, and, second, even if two boards have the exact same number of tiles for each color the placement of the two colorings can dramatically affect the expectation of the board. It can be shown that this board in Figure 4.2 is the worst possible board in the game in terms of expected value.

1	1	1
1	1	2
1	1	1

Figure 4.2: Worst bingo board.

<i>r</i>	0	1	2
<i>X</i>	0	6	8

Figure 4.3: Scorecard for bingo board in Figure 4.1.

4.4. Example

Figure 4.4 displays the scorecard for the bingo board from Figure 2.7. From this we see that the expected value is $E(X) = 2.5853$, which is much stronger than the two previous examples.

<i>r</i>	0	1	2	3
<i>X</i>	0	3	6	8

Figure 4.4: Scorecard for bingo board in Figure 2.7.

4.5. Example

In Figure 4.5, the six example boards from Figure 2.3 are depicted with their expected values computed. We can see that the best board is the only board with five distinct colors, which has an expected value of 1.70. The second best board is the only board with three distinct colors, which has an expected value of 1.77. This board is only a little bit weaker than the 5-colored board. In fact, it is much stronger than the two 4-colored boards available.

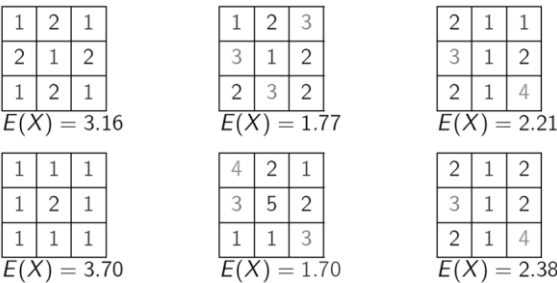


Figure 4.5: Expected values of bingo boards from Figure 2.3.

Even though the 3-colored board is more likely to obtain blackout, it can only obtain a bingo in the case of blackout or a single bingo if $E_{2,3}^3$ occurs, unlike the 4-colored boards, which can get bingos in several different events.

4.6. Example

Figure 4.6 depicts two 4-colored bingo boards. Which is the safest choice for *Mario*? Their scorecards are computed in Figures 4.7 and 4.8. Note that the abstracted boards are not necessary for these calculations.

Instead, all that is needed is the ability to count the bingo combinations and knowledge of the probabilities in Table 3.1.

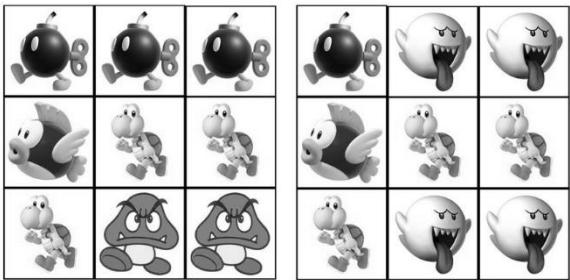


Figure 4.6: Two 4-colored bingo boards (ecsaul23, 2016, CC-NC-SA 2.5 license).

<i>r</i>	0	1	2	3	4
<i>X</i>	0	1	6	13	8

Figure 4.7: Scorecard for the first bingo board from Figure 4.6.

<i>r</i>	0	1	2	3	4
<i>X</i>	0	0	6	14	8

Figure 4.8: Scorecard of the second bingo board from Figure 4.6.

Therefore, the expected values of the two boards, respectively, are 2.21 and 2.28. Thus, the first board is the safer board (but only slightly) even though it has a 1-color bingo and the second does not. This comes from the fact that for a 4-colored board rolling exactly three colors is more likely than rolling exactly one color and thus the extra 3-bingo in the second board’s scorecard is more dangerous than the extra 1-bingo in the first board’s scorecard.

Those familiar with statistics or probability are certainly aware that the mean (or expected value) is not always the best measure of middle. For a random variable, the *median* m is the unique value such that $\mathcal{P}(X \leq m) \geq 0.5$ and $\mathcal{P}(X \geq m) \geq 0.5$. It is an alternative measure of center that is not easily skewed by atypical extremal values, unlike the mean. For boards with fewer colors, such as three, the 8-bingo blackout event may seem more of an outlier in terms of bingos obtained, that is, it is significantly larger than all the other possibilities. Consider, for example, the 3-color board from Figure 2.3. The scorecard for this board is 0,

0, 3, 8, respectively, which shows that the outcome of 8 bingos is disproportionate to any other outcome with this card. For this 3-color board, the median value is $m = 0$, compared with its expected value of $E(X) = 1.77$. For the 5-color board and the two 4-color boards, the median is $m = 1$. The first 2-color board has a median of $m = 2$ and the other has a median of $m = 4$. For most of these boards, the mean and median say the same story about the bingo board, but the median suggests the 3-color board may be the best board for *Mario* in this game. Thus, *Mario* would do well to consider both types of averages, mean and median, when selecting a board, especially with board with few colors. In addition to measures of center, measures of spread, such as variance and standard deviations, offer yet more strategies to judge the strength of a bingo board.

5. Alternate Selection Strategies for Player with Few Lives

Recall that at the beginning of *Bowser Party*, *Mario* has six lives. This means that a blackout can easily knock *Mario* out of the game. It is possible through skill and luck for *Mario* to collect additional lives, but based upon the gaming skill of *Mario* and *Bowser*, these additional lives might only serve to mitigate lives lost in previous *Bowser* mini-games. In other words, blackout is devastating for *Mario*, although it is survivable by skilled players. In this consideration, the best way to avoid blackout is to choose a board with the most number of distinct colors. This is a valid strategy for *Mario*, but the Law of Large Numbers tells us that repeated success in *Bowser's Bogus Bingo* will occur when using expectation instead of avoidance of blackout.

Now, if *Mario* has a single life left, obtaining one bingo is equally as devastating as obtaining blackout. Also, it can be shown that all boards in the game have an expected value greater than one. Thus, we would not expect *Mario* to survive the mini-game. For *Mario*, the goal is not to minimize the number of lives lost but instead the goal is simply survive the mini-game, that is, to lose no lives. As such, the selection strategy to be used is simply to choose the bingo board with the highest probability of zero bingos.

5.1. Example

Consider the six boards in Figure 2.3 and suppose *Mario* has only one life remaining. Then the event $X = 0$ is the event that no colors are rolled for his board. Then the event $X = 0$ for these six boards is found in Table 5.1, respecting the same order as in Figure 2.3.

Table 5.1: Zero events of the six boards from Figure 2.3

$E_0^2 \cup E_2^2$	$E_0^3 \cup E_1^3 \cup E_2^3 \cup E_3^3 \cup E_{1,3}^3$	$E_0^4 \cup E_2^4 \cup E_3^4 \cup E_4^4 \cup E_{2,4}^4 \cup E_{3,4}^4$
$E_0^5 \cup E_2^5$	$E_0^5 \cup E_1^5 \cup E_2^5 \cup E_3^5 \cup E_4^5 \cup E_{1,2}^5 \cup E_{1,4}^5 \cup E_{2,3}^5 \cup E_{2,4}^5$ $\cup E_{2,5}^5 \cup E_{3,4}^5 \cup E_{3,5}^5 \cup E_{4,5}^5 \cup E_{1,4,5}^5 \cup E_{2,3,4}^5 \cup E_{2,4,5}^5$	$E_0^4 \cup E_2^4 \cup E_3^4 \cup E_4^4 \cup E_{3,4}^4$

Using the probabilities from Table 3.1, we compute the probabilities, found in Table 5.2, that each board will obtain zero bingos, respectively:

Table 5.2: Probabilities that the six boards from Figure 2.3 will have no bingos

$\mathcal{P}(X = 0) = 0.4019$	$\mathcal{P}(X = 0) = 0.5023$	$\mathcal{P}(X = 0) = 0.2321$
$\mathcal{P}(X = 0) = 0.4019$	$\mathcal{P}(X = 0) = 0.3557$	$\mathcal{P}(X = 0) = 0.1588$

We see that when *Mario* has only one life remaining, the 3-color board is his best choice, with either of the 2-colored boards being equally second. The 5-color board is the fourth best choice, which may be odd considering that when *Mario* has copious lives this is the best choice of board.

5.2. Example

Continuing the previous example, suppose now that *Mario* has exactly 2 lives remaining, that is, *Mario* can afford to lose one life but not two. These probabilities are reported in Table 5.3. We see that the ranking changes some.

Table 5.3: Probabilities that the six boards from Figure 2.3 will have no more than one bingo

$\mathcal{P}(X \leq 1) = 0.4019$	$\mathcal{P}(X \leq 1) = 0.6721$	$\mathcal{P}(X \leq 1) = 0.5756$
$\mathcal{P}(X \leq 1) = 0.4019$	$\mathcal{P}(X \leq 1) = 0.5525$	$\mathcal{P}(X \leq 1) = 0.5756$

While the best board is still the 3-color board, we also see that the 4-color boards are now equally the second best, which might be odd since one of the 4-color boards was the worse choice when *Mario* has only one life. The 5-color board is still fourth and the 2-color boards are now equally the worst choice for *Mario*, even though they were the second best choice for *Mario* when he has one life. Similar calculations can be found when *Mario* can afford to lose two lives, three lives, etc.

Conclusions

In conclusion, different *Team Mario* players will value different bingo boards at different levels based upon their reservoir of lives. Players with a copious amount of lives are better off to gamble with a board with smallest expected value or median. Players whose survival is in serious jeopardy are best to choose a board with the highest probability of few bingos. We have seen that these strategies are incongruent. Ideally, if *Team Mario* works cooperatively, as they should, the players with fewer lives should be allowed to pick their boards first based on the strategy from Section 5, leaving the remaining boards to be chosen second by the remaining players based on the strategy from Section 4. This will best protect *Team Mario* from the clutches of Bowser.

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A Diffusion-Limited Titration Using Microfluidics

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Abstract

Microfluidic devices offer the ability to precisely control liquids. Current industrial fabrication methods are very efficient in producing large quantities of microfluidic devices, but designing and producing a single, specialized device can be cost prohibitive for this method. We report a sacrificial method of fabricating microfluidic devices with polydimethylsiloxane and magnesium wire. This method provides a cost-effective way to produce single microfluidic devices. Devices produced using this method are capable of inducing laminar and turbulent flow. We demonstrate the potential of this fabrication method, conducting an acid/base titration in which the mixing of analytes comes solely from diffusion of ions from one solution to the other. Using our device and the diffusion-limited titration described, we can differentiate between three types of acid/base titrations—strong acid/strong base, weak acid/strong base, and strong acid/weak base—while also obtaining approximate solution concentration. These diffusion-limited titrations can be monitored and analyzed as the reaction is occurring.

Introduction

Microfluidic devices are specialized chemical analytical tools that contain channels with dimensions on the order of micrometers through which nanoliters of fluids flow. On this small scale, many of the behaviors normally exhibited by fluids can be controlled. This means we can perform experiments with fluids in these channels with great control.¹⁻³ Additionally, devices use minimal reagents and create very little waste. Microfluidic devices are often fabricated from materials that are elastomeric in nature such as polydimethylsiloxane (PDMS) or other substrates.⁴⁻⁶ In the most commonly employed fabrication methods, the device is fabricated using a master, which is fabricated using methods such as etching and photolithography.⁷⁻⁹

One of the primary methods microfluidic devices use to control the behavior of fluids is switching between laminar flow and turbulent flow.¹ In a narrow, linear channel at low flow rates, laminar flow—fluid flowing in orderly sheets—is usually observed. Under these conditions, fluids can flow next to each other through a microchannel without mixing together. Turbulent flow involves chaotic, twisting patterns of flow and is often observed at high flow rates or when the flow is obstructed. In turbulent flow, particles in a fluid mix together seemingly randomly. This is similar to the flow in a fast-flowing river with rocks and rapids. For a microfluidic fabrication method to be able to create fully capable devices, the devices made must be able to control whether laminar or turbulent flow occurs at any given time.

One of the main goals of microfluidics is to create a single device that can perform a complete molecular analysis of a solution, or in other words, to create a device that can analyze both small molecules such as metabolites and large molecules such as proteins.^{10,11} This concept has been called a “lab on a chip.” The idea is that a researcher can inject their sample, and any required analysis or synthesis takes place before the fluid exits the device. Some devices are geared toward chemical analysis such as biological assays.¹² In other devices, the total synthesis of a product can take place, such as the synthesis of silver nanoparticles,¹³⁻¹⁵ other nanostructures,¹⁶ and many chemically useful products such as azo dyes,¹⁷ metal organic frameworks (MOF),¹⁸ and other organic compounds.^{19,20} Finally, microfluidic devices have applications in the field of medicine, such as devices to analyze interactions between biological molecules,²¹ testing blood or urine samples,²²⁻²⁴ and even early detection of birth defects.^{25,26}

In this paper, we present a novel method of fabricating PDMS-based microfluidic devices. Rather than using typical mass-fabrication

methods, we use a sacrificial method to fabricate individual devices. Using sacrificial substrates to shape microfluidic channels is a well-known technique in the fabrication of individual microfluidic devices. Sacrificial substrates come in many varieties including phase-changing polymer layers,²⁷ shellac microfibers,²⁸ and numerous other innovative methods.^{29–36} We chose to use Mg wire as our sacrificial substrate over other methods because of its relative inexpensiveness and ease of the associated sacrificial process. In our devices, the goal is to perform an acid/base titration (a 1-to-1 reaction between acid and base where one analyte is completely used up). In our titration, an acid will flow next to a base in the same channel with little or no bulk solution mixing (under laminar flow). Any mixing that does occur is due to the diffusion of ions from one species into the region of the other. Analyzing the concentration gradient resulting from this ion diffusion will allow us to characterize the solutions.

Experimental Methods

Device Fabrication

To fabricate our devices, 200- μm -thick Mg ribbons (Fisher Scientific) were cut into shape using wire cutters. As shown in Figure 1, the devices used in this research contained channels with two initial inlets for the acid and base analytes, a main channel about 3 cm in length and 2–3 mm wide, up to four additional inlets at the end of the main channel to allow standard addition, and an outlet.

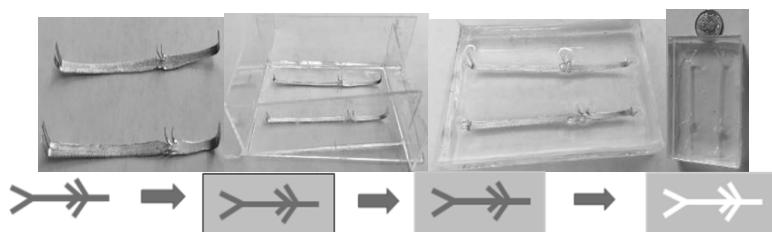


Figure 1: Device fabrication schematic. First, the strip of Mg is shaped with wire cutters. Second, the wire is placed in the glass box on top of a thin layer of hardened PDMS. Third, more PDMS is poured, submerging the Mg wire. After baking, the glass box is removed. Fourth, the device is placed in the sonicator, where the Mg wire is dissolved by HCl. A dime is shown for scale.

PDMS (Sylgard 184, Dow Corning, Midland, MI) was mixed together in a 1:10 polymerizer:base ratio. This mixture was stirred for 10–

15 minutes and then placed in a vacuum ($\sim 3\text{--}4$ torr for 1 hour). A small amount of the resulting PDMS mixture was then poured into the base of a 2×3 -inch glass box. Enough was poured in to form a layer of PDMS and completely cover the glass. The glass box containing the PDMS layer was placed in an oven at 110°C for 10 minutes. This baking polymerized the PDMS and formed a transparent layer on the bottom of the box. The Mg ribbon template was then placed in the center of the box on the PDMS layer. More liquid PDMS was poured over the Mg, covering all of the wire except for the tips of the inlets and outlets that were bent upward. The device was again baked in the oven for an additional 15–20 minutes. After this baking period, the device was taken out, and small steel wires were pressed against the small Mg tips protruding out of the PDMS. More PDMS was poured onto the device until the Mg tips were completely submerged (but not the steel tips). The device was baked again at 110°C for about 1 hour. After this final baking, the device was taken out of the glass box, and the steel wires were gently removed with pliers.

Sonication

The most time-consuming step in the fabrication of microfluidic devices using the PDMS method is the sonication/acid dissolution of the Mg, in which hydrochloric acid (HCl) dissolves the Mg wire, leaving the finished channel. To find the optimal conditions for sonication, we made a series of 15 identical microfluidic devices with a 1-cm-long channel. The concentration of HCl used in the sonication was varied from 1 M to 0.001 M. Five devices were placed in glass beakers containing ~ 80 mL of each solution in the sonication bath (Branson 2800). We tracked the sonication and recorded the time when each device finished sonicating (when the Mg wire was completely dissolved). Based on our data from this experiment, 100–500 mL of a 1 M HCl solution was used to sonicate devices. The sonication facilitated the reaction between the HCl and Mg(s) in the device. This reaction produces $\text{H}_2(\text{g})$ and the water soluble salt Mg chloride (MgCl_2). In other words, the Mg metal that formed the channel template was dissolved away. The sonication helped the hydrogen bubbles to escape the channel, allowing more acid to reach the remaining metal, leaving an empty channel.

Device Fabrication

As shown in Figure 2, sonication time was inversely related to HCl concentration, with the 1 M solution requiring about 20 hours and the

0.001 M solution requiring about 800 hours. As can be seen in the inset plot, the sonication reaction is 0.582 order with respect to HCl.

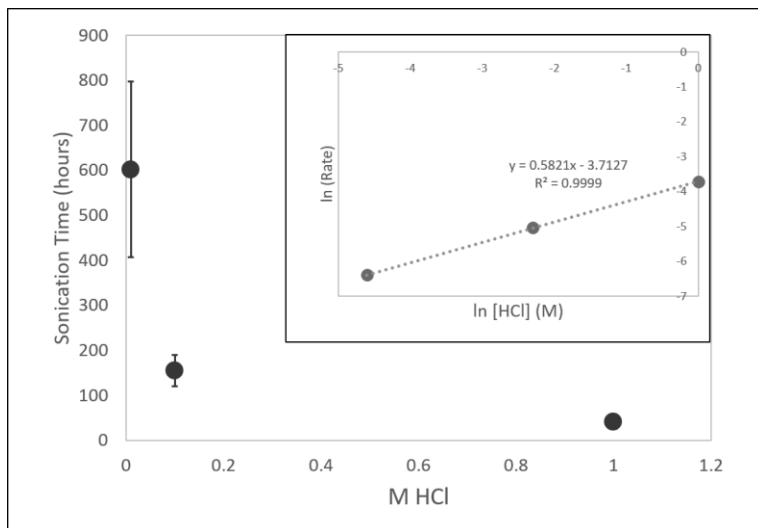


Figure 2: Sonication data. This figure shows the conditions that were tested to find the optimal sonication conditions. The graph shows that sonication time decreases as [HCl] increases. The inset graph shows a plot of the natural log of the [HCl] with the natural log of the rate (1/time).

Flow Regimes

To be a fully functioning microfluidic device, the device must allow us to manipulate the mechanics of fluid flow, or in other words to switch between laminar and turbulent flow. Laminar flow is indicated by two liquids flowing side by side without mixing (except for small-scale diffusion). In our fabrication method, to generate laminar flow the Mg wire was made straight and flat. To generate turbulent flow, a twist was added to the Mg wire. To demonstrate that this results in turbulent flow, we made devices that contained sections of flat, straight channels and sections where the channel contained twists. We pumped two fluids through the device simultaneously. One of the fluids contained a fluorescein/water solution, and the other contained red food coloring in water. To illustrate that our devices meet the criteria for microfluidic functionality, we used a fluorescence microscope to take pictures of the channel containing the fluids at 3 points on the device: immediately beyond the injection point of the two fluids; near the end of a long, straight section that included a curve in the channel; and immediately after the twist in a

channel (Figure 3). Using syringe pumps and a fluorescence microscope, we obtained pictures at the aforementioned positions at varying flow rates. We tested flow rates of 5 $\mu\text{L}/\text{min}$, 133 $\mu\text{L}/\text{min}$ and 999 $\mu\text{L}/\text{min}$, as illustrated in Figure 3.

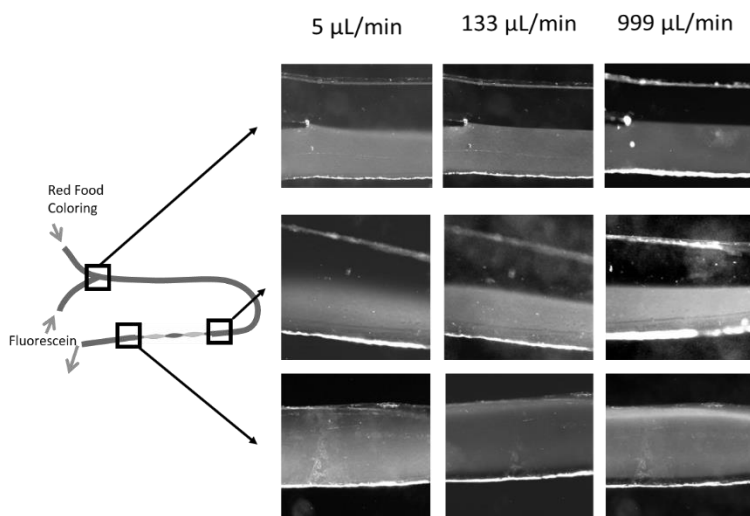


Figure 3: Flow regime determination. This figure shows a device that was fabricated to test flow regimes. Three locations in the channel were selected to demonstrate the device's ability to induce laminar or turbulent flow. Photographs were taken at three flow rates. At the inlet and before the twist (top row), we see the fluids flowing side by side with minimal mixing. This tells us that laminar flow is being observed. After several cm, the flow is still laminar (middle row). After the twist, the solutions have mixed at all 3 flow rates, indicating turbulent flow (bottom row), although the mixing is not perfect as illustrated by the brighter and darker regions in the bottom row.

Diffusion-limited Titration

To perform a diffusion-limited titration, we fabricated a specialized microfluidic device relying on laminar flow. In a typical (macroscale) titration, the two analytes are mixed together thoroughly as the titration occurs. For our titration, we created an environment in which the only mixing of the two analytes comes from the diffusion of ions of one species into the other. Thus, our titration was diffusion-limited. Our device was designed to have two initial inlets (labeled acid and base in Figure 4), where the acid and base participating in the titration were introduced,

and a long straight channel where the two species were allowed to diffusionally mix. Note that only laminar flow is taking place here so this is where the diffusion-limited titration is taking place. At the end of this long channel, additional inlets on either side of the channel introduced standard solutions to facilitate analysis. After the injection points, all solutions (titrating solutions and standards) flow together side by side within the channel. At this point, a photograph is captured with the fluorescence microscope to observe what has taken place, as shown in Figure 4. The standard reference solutions allowed the verification of unmixed pH, but were not used in analysis other than that.

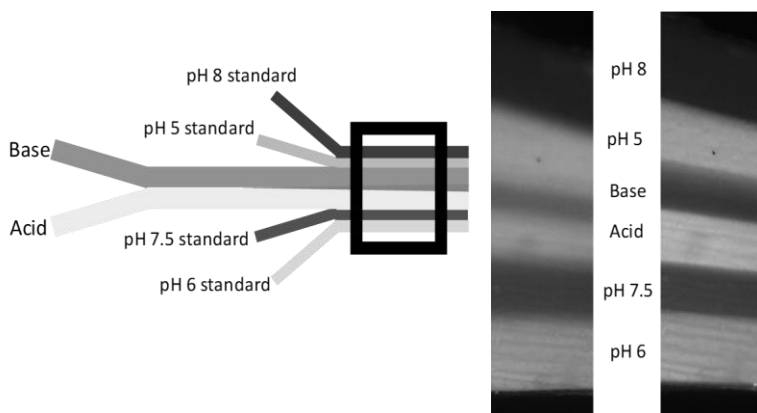


Figure 4: Microfluidic titration schematic. The layout of the device in which we performed the diffusion-limited titration. At left are the initial inlets where the acid and base participating in the titration were injected. After the channel is merged to allow the diffusion-limited titration to occur, standards were added (inlets before the black box). Immediately after the secondary inlet is where photographs were taken with the fluorescence microscope (black box). The two images on the right are examples of the photographs taken at different flow rates. The image at left that shows more mixing of analytes was taken at a flow rate of 10 $\mu\text{L}/\text{min}$ (for all solutions) and the image at right was taken at 200 $\mu\text{L}/\text{min}$.

All solution contained about 50 mM solution of morpholine fluorescein (for each run, the concentration was identical between all the solutions, but the concentration varied slightly between runs, the morpholine fluorescein was synthesized by Matthew Prater, a former student at SUU, as part of a class project), a pH-sensitive dye that fluoresces in acidic conditions (in the presence of H^+ ions). The acids and bases that were analyzed in this experiment were HCl, citric acid ($\text{C}_6\text{H}_8\text{O}_7$), sodium hydroxide (NaOH), and Tris base ($\text{C}_4\text{H}_{11}\text{NO}_3$). One of

the acids was always titrated against one of the bases, and the standard acids and bases used during each experiment were the same as the acid and base being titrated but at a carefully chosen pH. Tests were conducted using varying concentrations and pH values of the acids and bases involved in the titration.

For most analyses we analyzed flow rates of 200, 150, 100, 50, 40, 30, 20, 10, 5, and 3 $\mu\text{L}/\text{min}$ (in that order).

Morpholine Fluorescein Titration

In a standard analytical titration, the reaction progress can be monitored with a pH meter or an indicator dye. To measure pH values in our experiment, we added morpholine fluorescein, a pH-sensitive indicator, to all solutions. To relate the fluorescence intensity of this dye in our solutions and during the titration to the solution pH, we conducted a fluorometric titration. To do this, a solution of morpholine fluorescein was adjusted to an initial pH of ~ 2 with HCl. A small sample of the solution was transferred into a plastic cuvette and placed in the fluorometer, and the fluorescence intensity of the solution was measured. The sample was transferred back into the beaker, and the acid solution was slowly titrated with NaOH. After every few drops of titrant were added, the fluorescence was measured again. This process was repeated until a pH of ~ 12 was reached as seen in Figure 5. This allowed us to see how the fluorescence intensity of morpholine fluorescein changed as a function of pH.

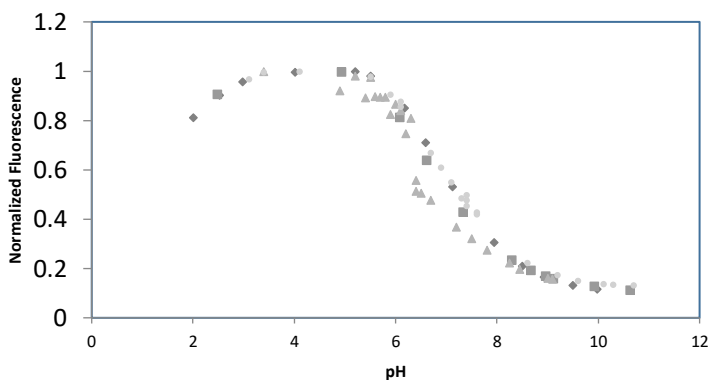


Figure 5: Morpholine fluorescein titration. This figure shows the normalized data from multiple morpholine fluorescein titration experiments (each run represented by a different shape of points). The peak intensity for this dye is at pH ~ 4 , the lowest intensity at pH ~ 11 . Note the “hook” effect of the fluorescence at pH < 4 .

Results and Discussion

Analysis

The fluorescence in a diffusion-limited titration experiment was measured using a line profile perpendicular to the direction of fluid flow. High intensity indicates high acid (H^+) concentration whereas low intensity indicates higher basic (OH^-) concentration. The data from this intensity profile were exported to Excel and grouped as the fluorescence data for that specific flow rate. This was repeated for each flow rate. Line graphs showing changes in fluorescence in the channel for each flow rate were constructed.

In Figure 6, we see the data graphed from a strong acid/strong base titration and from a weak acid/strong base titration. The shapes of the lines are obviously different. In Figure 6A, the H^+ ions from the strong acid are moving into the basic solution, illustrated by the leftward movement of the high intensity region as flow rates decrease. In Figure 6B, the OH^- ions from the basic solution move into the acidic solution, shown by the rightward movement of the lines. The right or leftward movement of the lines is largely due to the concentration of the solutions, as will be discussed later.

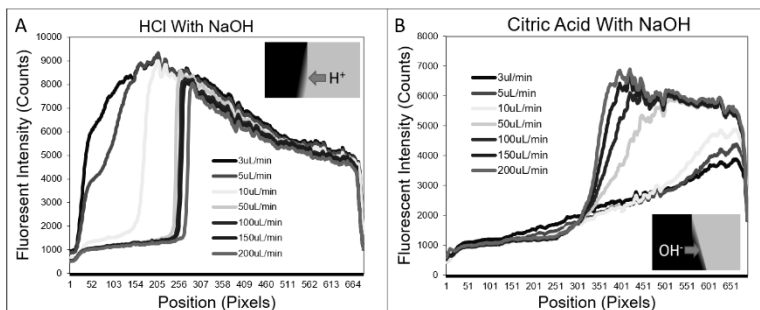


Figure 6: Acid/base titration. Data for two separate acid/base titrations are shown. Each line represents a photograph taken at a specific flow rate. A) The titration between HCl and NaOH, with HCl on the right side and NaOH on the left. The inset image shows the general movement of H^+ ions that was observed. B) The titration between citric acid and NaOH, with the acid again on the right side. In this titration (as illustrated by the inset figure), it was the OH^- ions that were able to diffuse across the channel. In both runs shown, the acids had a pH of 4 and the NaOH had a pH of 9.

Slope Characterization

For the titrations shown in Figure 6, the HCl and citric acid solutions were approximately the same concentration (both 1.0×10^{-4} M). Each line has a region where it transitions from low to high fluorescence intensity. This region represents the pH gradient created within the microfluidic channel as the titration took place. The slope of the line in this region is related to how much diffusion has taken place.

In a further analysis, the slope of each line in the transition region was found and these slopes were plotted vs the flow rate. Figure 7 shows the slope data from the two titrations shown in Figure 6. As can be seen in the Figure 7, the strong acid/strong base data have higher (steeper) slopes than the data from the weak acid/strong base.

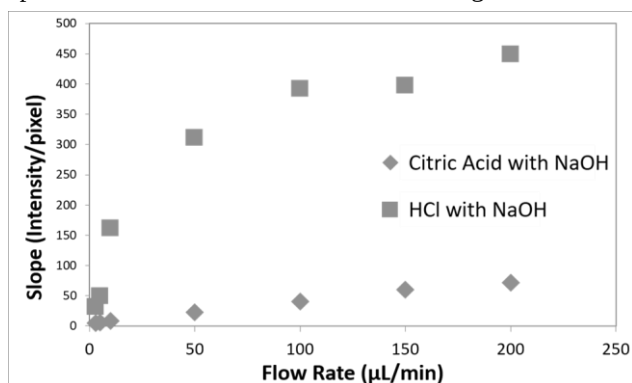


Figure 7: Slope characterization. The slope of the acid/base transition for each flow rate was graphed vs. the flow rate for the runs shown in Figure 6. The strong acid has a much steeper line, because of the greater $[H^+]$ in that run.

As can be seen in Figure 7, there are obvious differences in the values of slopes in the region of diffusion between a titration of a strong acid/strong base and that of a titration of a weak acid/strong base. Using this method, we could take a 1.0×10^{-4} M unknown acid solution and titrate it with a strong base and determine whether that acid is strong or weak. A strong acid would exhibit steeper slopes at all flow rates but particularly at high flow rates. The titration of a weak acid would have a much less steep slope to begin with and decrease gradually and relatively linearly as flow rates decrease.

Position Characterization

In a different experiment, we made the acidic solutions to be approximately the same pH (they therefore differed in concentration based on differing K_a values). In these graphs, the slopes of the lines were too similar to analyze using the slope characterization method discussed above. Rather, we looked at the direction the pH gradient traveled from a designated starting point. We started with a line graph of intensity profiles for a specific titration, found the middle point of the transition from high to low intensity of the line corresponding to the highest flow rate (200 $\mu\text{L}/\text{min}$), and designated that as the starting point. We assumed that a negligible amount of diffusion had occurred at this point. This is a reasonable assumption, as the fluid residence time in the channel at that point is small (a few seconds). As the flow rates are decreased, the diffusion region of each line will shift either to the left or to the right of the starting point, depending on whether H^+ or OH^- diffusion dominated. In all our graphs, we have the acidic species on the right side of the graph

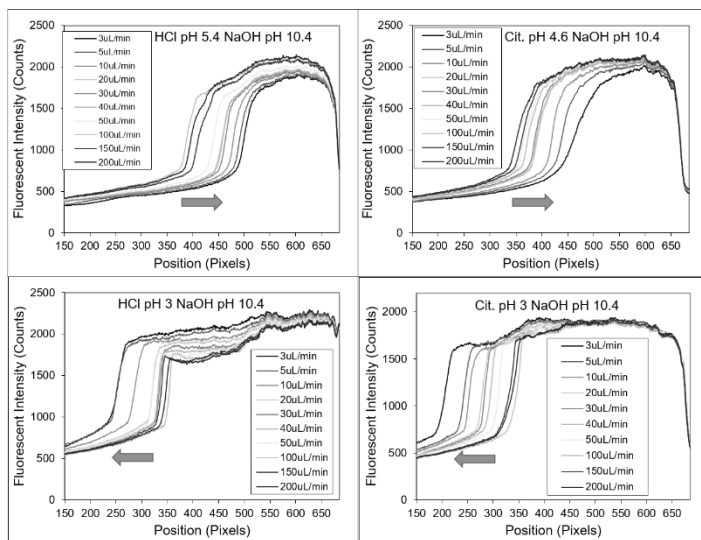


Figure 8: Position characterization. Four titrations are shown. (Top row) Acid/base transition lines that are moving to the right. This means that the basic ions are diffusing across the channel and consuming the acids. Note that in these titrations, both acids are rather dilute. (Bottom row) Acid diffusing across the channel and consuming the base, as these acids are much more concentrated than the acids in the titrations on top. The arrows below the graphs go from high flow rates to low flow rates.

and the basic species on the left. If the lines shift to the left, the H^+ ions from the acid solution are diffusing into the basic solution and consuming OH^- , making the solution more acidic. If the lines shift the right, the OH^- ions are diffusing into the acidic solution and consuming the H^+ ions. We found that concentration, not acid strength (pKa), determines whether the lines move right or left (Figure 8).

Using this second method of analysis, we can determine information about the pH values of the analytes being used. Note that the same trends were observed regardless of pKa value.

Conclusions

Using our sacrificial Mg wire-based method for fabricating microfluidic devices as described above, we have created a series of functional microfluidic devices. The cost of this production method per device type fabricated is significantly less than that of photolithographically fabricated devices. By taking advantage of laminar flow, we were able to perform side-by-side analysis of multiple analytes (acids and bases) and internal standards within the same microfluidic channel. The chemical interactions we were interested in observing within the device were the diffusion of ions from an acid to the adjacent flowing base and vice versa. By adding a pH-sensitive dye (morpholine fluorescein) to each solution to act as an indicator, we were able to track the diffusion of ions within the channel with a fluorescence microscope. Taking an intensity profile of the pictures on the microscope showed us how the ions were diffusing. In other words, this gave us analytical data about the microscale acid/base titration that had taken place in the channel because of diffusive processes, such as pH of the solutions used and relative strengths of the acids and bases.

Acknowledgments

We would like to thank the Walter Maxwell Gibson Fellowship and the Southern Utah University's Faculty Scholarly Support Fund for financial aid in the form of grants to purchase the materials necessary to perform the experiments for this research. We would like to thank Matthew Prater, Colton Loftus, Jonathan Wickes, Chris Lamb and Laikin Barney for their contributions to the research and to this paper.

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The Effects of Radio Jet Feedback on Star Formation in Satellite Galaxies

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Southern Utah University

Abstract

Most massive galaxies host black holes, and the size of the black hole is closely correlated with the mass of the galaxy. This tight correlation indicates that black holes play an important role in regulating the star formation in the host galaxy. In addition, many black holes produce powerful jets of relativistic particles that extend far beyond the host galaxy. Since galaxies tend to be rather close together, these jets are capable of interacting with other nearby galaxies. In some cases, this interaction can trigger star formation by compressing gas clouds, which then collapse and form stars. In other cases, the jet heats and expels the galaxy's cold gas, quenching star formation. Although both scenarios have been observed, it is not known which is more likely. We investigate this by examining the colors of the satellite galaxies of a sample of 58 jet galaxies. An excess of blue galaxies outside the jets is observed, accompanied by an excess of red galaxies inside the jets. These results indicate

that, on average, interactions with galaxy jets tend to quench star formation. We also examine the colors of galaxies that are affected by the jets to determine whether being closer to the source of the jet has a greater impact on star formation. We find no correlation between color and proximity to the source of the jet, which indicates that any interaction with the jet is sufficient to quench star formation in satellite galaxies.

Introduction

Thanks to large-scale, multiwavelength surveys, we now know that essentially all large galaxies host supermassive black holes (SMBHs) in their centers (e.g., Magorrian et al. 1998). These black holes appear to be as old as the galaxies themselves, and there is a linear relationship between the mass of the SMBHs and their host galaxies: larger galaxies host more massive black holes (Marconi & Hunt 2003). While the full extent of this relationship is still being explored, the fact that it is linear suggests that galaxies and their SMBHs influence each other in some way. One way in which this probably occurs is via feedback from the black hole.

As black holes consume gas, the material forms an accretion disk as it approaches the SMBH (Shakura & Sunyaev 1973; Hine & Longair 1979). Black holes are tiny, so only a small fraction of the infalling material actually enters the black hole, while most of it is ejected away, in much the same way that attempting to fill a cereal bowl with a fire hose will result in most of the water being ejected, with very little remaining in the bowl. This outflowing material may be the feedback mechanism by which black holes affect star formation in their host galaxy.

Occasionally, the ejected material leaves the black hole in the form of a collimated relativistic jet, which is typically detected in the radio portion of the spectrum. Galaxies hosting such jets are known as radio galaxies. In many cases, the jets eject material completely out of the host galaxy and may even interact with other galaxies that are found near the host galaxy. Such small, nearby galaxies are called satellite galaxies, because they tend to orbit the larger galaxy in the same way that smaller moons orbit larger planets.

The effects of radio jets on these satellite galaxies are poorly understood, but the jets probably affect star formation. Stars are born in collapsing gas clouds, but these clouds need something to trigger their collapse. Interactions with these radio jets could cause cloud collapse and trigger star formation. A few examples of this have been observed in nearby radio galaxies (Hardcastle et al. 2007; Inskip et al. 2008). However, these jets have also been observed to quench star formation as they

heat and expel gas from galaxies (Shabala et al. 2011). It is not yet clear which effect (triggering or quenching star formation) is more common.

The goal of this project is to examine a sizeable sample of radio galaxies and compare the colors of satellite galaxies inside the path of the jet with those outside the jet. This will allow us to examine the star formation histories of galaxies that have been impacted by radio jets. We also aim to investigate whether being closer to the source of the radio jet has a greater impact on star formation. For this project we used the following cosmological parameters: $\Omega_m = 0.27$, $\Omega_\Lambda = 0.73$, and $H_0 = 71 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

Sample Selection

Radio galaxies were selected from the ‘jet’ sample of the van Velzen et al. (2012) catalog of radio galaxies. Galaxies whose radio image did not include the entire jet were omitted. The nearest 58 galaxies were used, and this sample has a redshift range of $0.003 > z > 0.110$. Dereddened magnitudes and spectroscopic redshifts were retrieved from the 12th data release (DR12; Alam et al. 2015) of the Sloan Digital Sky Survey (SDSS). The distances as well as the lengths of the radio jets were derived from their redshift. AstroImageJ (Collins et al. 2017) was used to measure the areas of the radio jets.

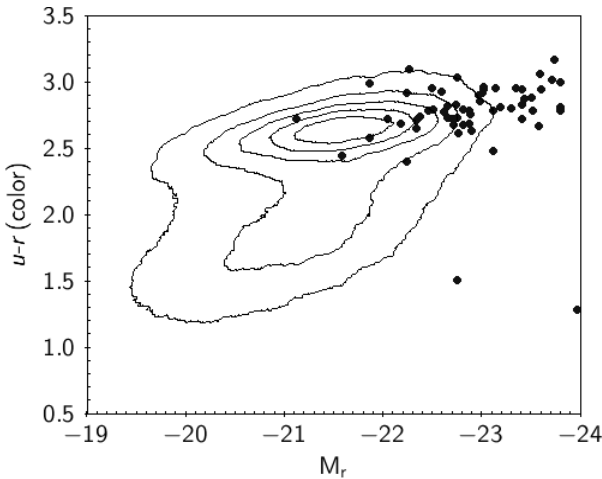


Figure 1: Color-magnitude diagram showing the relation of the radio galaxies in our sample to 150,000 SDSS galaxies. The radio galaxies tend to lie on the massive end of the red sequence.

The colors and luminosities of galaxies can be used to examine and compare their evolutionary histories. The $u-r$ color is a comparison of a galaxy's u (ultraviolet) apparent brightness to its r (red) apparent brightness. Galaxies with a larger $u-r$ value are redder than those with a smaller value. Figure 1 is a color-magnitude diagram that shows the $u-r$ color and the r absolute magnitudes (i.e., luminosities) of the host galaxies in our sample (shown as dots). Contours show the distribution of magnitudes and colors for a random sample of 150,000 SDSS galaxies. This figure shows that most of the galaxies in the sample lie along the massive end of the red sequence (i.e., $2 \leq u-r \leq 3$ and $-21.5 \leq M_r \leq -24$).

Methods

With the sample of radio galaxies in place, we then retrieved data for the satellite galaxies in the vicinity of the radio galaxies. We searched SDSS DR12 for the photometric redshifts and g and r magnitudes of all satellite galaxies within a circle whose diameter is that of the respective radio jet. This was done to ensure that the satellite galaxies are within range of the jets.

Only some of the galaxies in this sample are physically near the host galaxy: the rest are in the foreground or background. To remove these unwanted galaxies, we compared the redshifts of the satellites to that of the host galaxy and removed those whose redshift was discrepant. Satellite galaxies are small and therefore faint, so their spectroscopic redshift cannot be measured. The photometric redshift must therefore be used. It is determined by comparing the satellite colors with models of galaxies of varying masses and star formation histories at a range of redshifts. The photometric redshift is approximate and must be used with some caution, so we applied a conservative limit and kept all galaxies whose photometric redshift is within 0.2 of that of the host galaxy. We retained galaxies with good photometry, so we used an apparent magnitude limit of $r = 22$. In addition, we required that the $g-r$ colors of the satellites were within $\sqrt{\sigma_r^2 + \sigma_r'^2} \leq 0.1$. Finally, because fainter objects cannot be seen with increasing distance (the Malmquist bias), we limited our sample of satellite galaxies to those with $M_r \leq -18$. Applying these conditions resulted in a final sample of 983 satellite galaxies.

Satellites were classified as either inside or outside the jet path by comparing visible light images of the host and satellite galaxies to radio images from the van Velzen et al. (2012) database. Those satellites that appear within the outer radio contour are considered to be in the (projected) path of the radio jet, while those outside this contour are, of course, considered to be outside the jet. This comparison was done for every satellite galaxy in the sample by at least two members of our team,

and the results were then compared to ensure that the visual inspection method was reproducible from person to person. We found that it was, as in all but a few (~ 10) cases both team members arrived at the same classification.

With the sample of satellite galaxies defined and classified, we were then able to compare the colors of the satellites inside the jets with those outside. When episodes of star formation occur, most stars produced are red, while a handful of blue stars are formed. These blue stars are large and can outshine millions of smaller red stars. Therefore, areas of recent star formation are blue. Large stars burn their fuel much more quickly than smaller stars, so these bright blue stars die after a few hundred million years, while the smaller, red stars continue to shine. This means that with the passage of time, groups of stars appear redder and redder as the bluer stars die. Because of this, color makes a good tracer of star formation history: areas of recent star formation appear bluer and areas lacking recent star formation appear redder.

Results

The $g-r$ color is a comparison of the galaxy's apparent brightness in the g (blue) filter to its apparent brightness in the r (red) filter. Galaxies with a higher $g-r$ value are redder than galaxies with a smaller value. Figure 2 shows the distribution of $g-r$ color of the satellite galaxies in our sample. Each bin, which has a width of $g-r = 0.05$, shows the number of satellite galaxies per host per square kiloparsec within that color bin. The black points and associated error bars are for satellites inside the path of the jets, while the gray points are for satellites outside the jet path. Errors were calculated as $\sqrt{n}$, where n is the number of galaxies in a given color bin. The vertical dashed line at $g-r = 0.7$ represents the rough division between blue galaxies (left of the line) and red ones (right of the line).

Looking at the blue galaxies, we see that in six bins there are approximately equal numbers of inside and outside galaxies that have those colors, while in seven bins there are more galaxies outside the jets than in that have those colors. As for the red bins to the right of the line, we see that in several bins there are equal numbers of galaxies, but for two bins there is a very large difference, with many more galaxies inside the jet being red than outside the jet. In general, we see that there tend to be more blue galaxies outside the jet than in, and we also see that there tend to be more red galaxies inside the jet than outside.

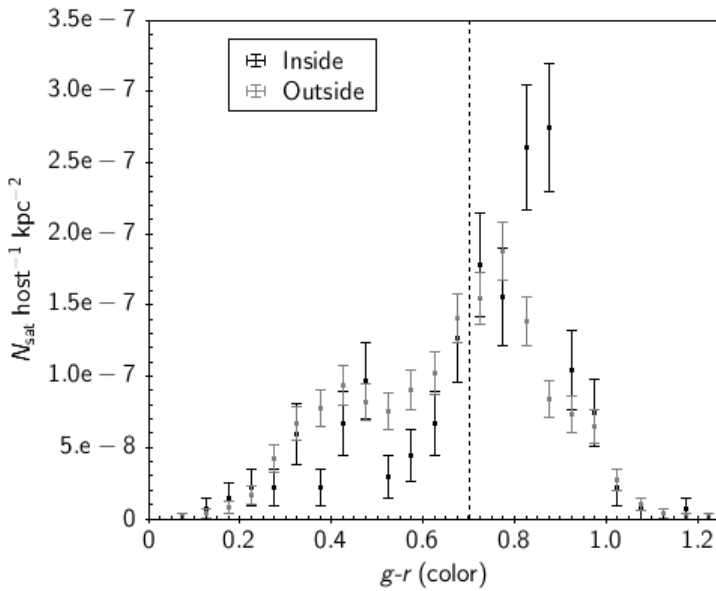


Figure 2: Color distribution of satellites inside (black) and outside (grey) the jet path. The vertical line at $g-r = 0.7$ is the division between blue (left) and red (right) galaxies. This figure shows a clear excess of blue galaxies outside the jet path, while there are more red galaxies inside the jet path.

Although we see that the color distributions are different, it is hard to see from the plot how large those differences are. Figure 3 shows the difference between the color distributions of the previous figure. For this plot, we subtracted the distribution of outside galaxies from that of the inside galaxies such that for a given color bin, if there is an excess of inside galaxies, a positive number will result, while an excess of outside galaxies will produce a negative number. Equal numbers of galaxies would give a difference of zero, which is shown by the horizontal dotted line. As before, the vertical line is the division between red and blue galaxies. We can now clearly see an excess of blue galaxies outside the jets, accompanied by a strong excess of red galaxies inside the jets. These differences are statistically significant, as in many bins the error bars do not overlap the zero line.

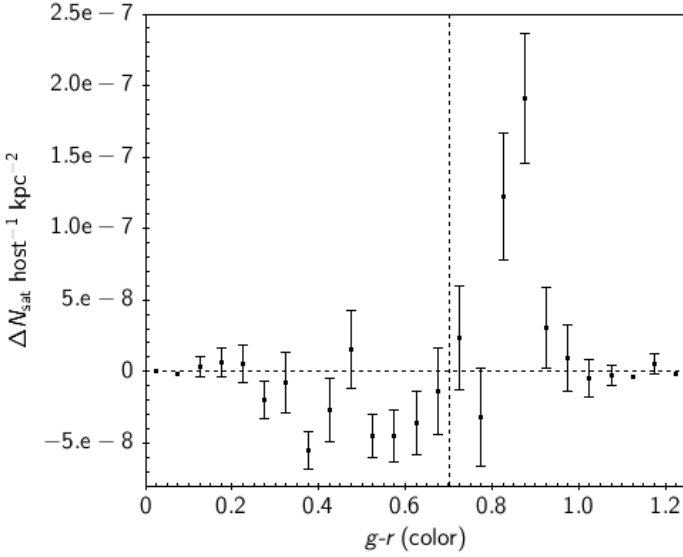


Figure 3: Plot of the difference of the color distributions of satellites inside and outside the jet path, shown with the division between blue and red galaxies. Positive values in a given bin indicate a greater number of galaxies inside the jet, while negative values indicate a greater number of outside galaxies. The vertical line at $g-r = 0.7$ is the division between blue (left) and red (right) galaxies. This figure shows a statistically significant excess of blue galaxies outside the jet, and a large excess of red galaxies inside the jet.

Discussion

There are three possible ways in which radio jets may impact satellite galaxies, and the color distributions of the satellites would be different in each case (Pace & Salim 2014). If, on average, radio jets had no effect on star formation, we might expect to see no difference in the color distributions of the inside and outside populations (i.e., the difference plot would be flat). In the event that radio jets trigger star formation, we would expect an excess of blue satellites inside the jets accompanied by an excess of red satellites outside, which would be manifest in the difference plot as a blue bump accompanied by a dip on the red end. Finally, if radio jets tend to quench star formation, we would expect to see a dip on the blue side accompanied by a bump on the red side. This last case is what is seen in the difference plot, which suggests that radio jets tend to quench star formation in neighboring galaxies. Quenching most likely occurs as the radio jet heats and expels the cold gas from the

galaxy, which prevents stars from forming. The timescale for this quenching must be rather small, as the lifetimes of radio jets are relatively short (~ 100 million years). Gravitational interactions with other galaxies may also play a role in quenching star formation (e.g., Kimm et al. 2009), but because we consider satellites both inside and outside the jets at a range of distances from the hosts, we would expect the quenching effects of interactions to be similar for all satellites in our sample.

Shabala et al. (2011) compared the colors of galaxies inside and outside the jet path for a sample of high-excitation (HERG: high power) and low-excitation (LERG: low power) radio galaxies and found that only HERGs quench star formation in satellites, while LERGs do not. Unfortunately, we do not have the HERG/LERG information for our sample, so we cannot directly compare our results with those of Shabala et al. (2011). However, since HERGs comprise only a few percent of all radio galaxies (Best & Heckman 2012), we can assume that most of the radio galaxies in our sample are LERGs. If so, then our results stand in contrast to those of Shabala et al. (2011). Interestingly, Pace & Salim (2014) also found that LERGs tend to have no effect on star formation. Although their sample of radio galaxies was larger, they did not compare satellites inside the jet path with those outside. We should point out that both the Shabala et al. (2011) and the Pace & Salim (2014) samples extended to higher redshifts ($z < 0.2$ and $z < 0.3$, respectively) while our sample only extends to $z < 0.11$. Because our sample of radio galaxies is restricted to more nearby galaxies, we are able to probe satellites down to smaller masses, and it is possible that the properties of these smaller galaxies are sufficiently different to produce the results we find.

In addition to comparing the colors of satellites inside and outside the jet, we examined the satellites in the jet path to determine whether galaxies nearer the host galaxy are more strongly impacted by the jet. We might expect that satellites closer to the source of the radio galaxy would experience the full force of the collimated jet, before it is slowed and disrupted by the intergalactic medium. Figure 4 shows the average color of the satellites in the jet path as a function of their distance from the host galaxy. The radio jets are of different lengths, so we divided the distance from the host by the jet length, such that satellites at the extreme end of the jet would have a distance of 1. In this figure, there may be a slight trend of galaxies being bluer the farther from the source they are, although the width of the error bars suggests that the trend is not significant. This plot suggests that distance from the radio jet has little effect on the average color of satellites. In other words, being hit by the jet in any way, regardless of how strongly, is sufficient to quench star formation in satellite galaxies. However, these results must be taken with some caution as this plot does not account for radio jet power. In future

work, we plan to analyze whether proximity, jet power, and halo mass affect satellite galaxy color.

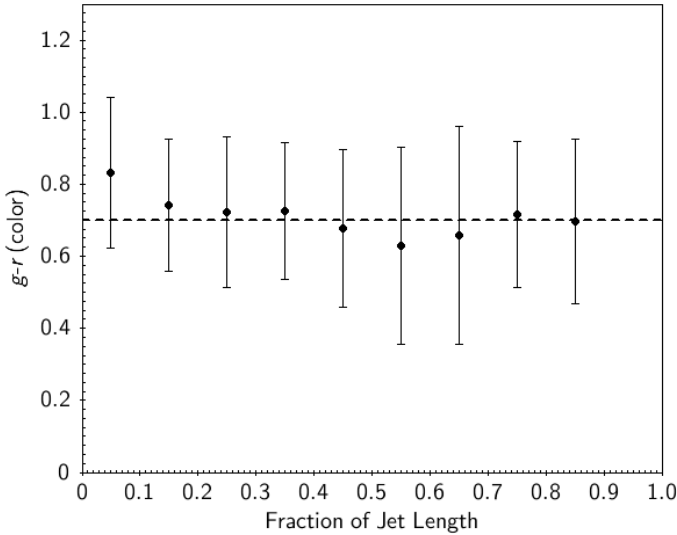


Figure 4: Distribution of the colors of satellites inside the jet path as a function of distance from the host. Although there may be a slight trend of galaxies being somewhat bluer with greater distance, the error bars suggest it is not significant.

Conclusion

In this work, we have found an excess of red satellite galaxies in the jet path of a sample of 58 radio galaxies. This excess is accompanied by an excess of blue satellites outside the jet, suggesting that radio jets tend to quench star formation in satellite galaxies. We have examined the average colors of satellites in the jet path to determine whether satellites closer to the source of the jet are more strongly impacted, and we find no correlation of color with distance from the host galaxy, which suggests that any interaction with the jet, regardless of how collimated it is, can quench star formation. In the future, we plan to expand on this project by using a larger sample of radio galaxies. We will also examine whether the radio luminosity and halo mass affect the colors of satellites in the jet path.

Acknowledgments

This study uses data from the SDSS Archive. Funding for SDSS-III has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, and the U.S. Department of Energy Office of Science. The SDSS-III web site is <http://www.sdss3.org/>. SDSS-III is managed by the Astrophysical Research Consortium for the Participating Institutions of the SDSS-III Collaboration including the University of Arizona, the Brazilian Participation Group, Brookhaven National Laboratory, University of Cambridge, Carnegie Mellon University, University of Florida, the French Participation Group, the German Participation Group, Harvard University, the Instituto de Astrofísica de Canarias, the Michigan State/Notre Dame/JINA Participation Group, Johns Hopkins University, Lawrence Berkeley National Laboratory, Max Planck Institute for Astrophysics, Max Planck Institute for Extraterrestrial Physics, New Mexico State University, New York University, Ohio State University, Pennsylvania State University, University of Portsmouth, Princeton University, the Spanish Participation Group, University of Tokyo, University of Utah, Vanderbilt University, University of Virginia, University of Washington, and Yale University.

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Using Exoplanet Transits to Characterize the Great Basin Observatory

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ABSTRACT

The Great Basin Observatory (GBO) became operational in August 2016. Since then, the telescope has gradually been utilized for scientific data collection. One project that has not been thoroughly explored is exoplanet transit observations. To determine the telescope's capabilities for exoplanet transit detection, we obtained photometric measurements of transiting exoplanet systems. Results were verified through comparison with expected values provided by the Exoplanet Transit Database. Several transits with depths >0.01 have been successfully analyzed. Characterizing the GBO's ability for transit observation will allow for a better understanding of the GBO's capabilities.

INTRODUCTION

The Great Basin Observatory (GBO) is located in Great Basin National Park, Nevada (Figure 1). The GBO is the first and only research-

grade telescope in a national park and had its first light in August 2016. It is managed by the Great Basin National Park Foundation in collaboration with four educational partners: Southern Utah University, University of Nevada-Reno, Western Nevada College, and Concordia University.



Figure 1. The Great Basin Observatory located at Great Basin National Park in Nevada. Photo by project manager Paul Gardner of Observatory Systems.

An exoplanet is a planet that orbits a star outside of the solar system. An exoplanet transit is when the planet passes in front of its parent star relative to the view from Earth. This temporarily prevents some of that star's light from reaching Earth. The star's change in brightness can be measured by continuous observation throughout the transit, as is illustrated in Figure 2. Data analysis allows for the determination of the transit's duration and change in magnitude (change in brightness) of the observed star.

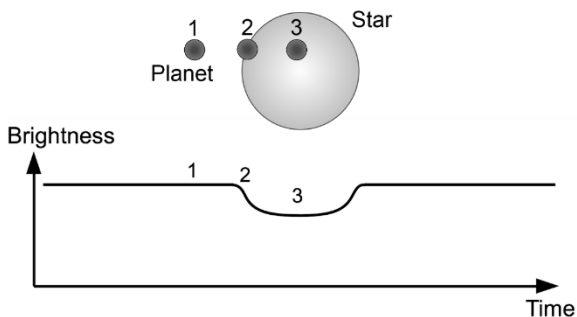


Figure 2. An illustration of an exoplanet transit and the corresponding light curve. The numbers represent a single planet at different positions during the transit.

The relative drop in brightness of a star during an exoplanet transit is represented by the transit depth. If we assume the stellar disc is of uniform brightness, and neglecting any flux from the planet or limb-darkening, the depth is the ratio of the observed change in flux (ΔF) to that of the stellar flux (F) with nothing transiting. The transit depth is also the ratio of the surface area of the star's disk that is blocked by the planet's disk. Thus, the depth can be related to the radii of the star (R_S) and planet (R_P) as:

$$\text{Depth} = \frac{\Delta F}{F} = \left(\frac{R_P}{R_S}\right)^2. \quad (1)$$

A transit depth of 0.02 is equivalent to a 2% drop in flux during transit.

We chose to observe exoplanet transits because they are abundant and well-studied, with over 3,700 confirmed detections worldwide (<https://exoplanetarchive.ipac.caltech.edu/>). Resources such as the Exoplanet Transit Database (ETD) (Poddany et al. 2010) provided ample transit information such as star magnitude, transit time, duration, and depth. Additionally, the ETD provided resources to model fit our data, which allowed for the determination of our observation's depth and duration. The ETD also allowed us to compare our results with the research conducted by other groups.

Since the GBO is relatively new, the sensitivity of the telescope for exoplanet detection was untested. We observed exoplanet transits in order to start quantifying the GBO's detection abilities. We began by observing transits with larger depths, then worked to measure transits of progressively smaller depths.

METHODS

The telescope at the GBO is robotic and is meant to be remotely operated. It is a Planewave CDK 700 with an aperture of 27 inches and a focal ratio of f/6.5. The SBIG STX 16803 camera has a field of view of 27×27 arcminutes and a plate scale of 0.4 arcsec per pixel. The telescope is equipped with 16 filters housed in 2 nested Finger Lakes filter wheels: LRGB, Ha, OIII, SII, BVRI, griz, and a diffraction grating.

We used the ETD to plan our transit observations. As part of our selection criteria, we had to consider the transit duration, depth, star magnitude, local weather at the GBO, and telescope availability. To measure a baseline flux for the star when not in transit, we tried to begin our observations one hour before the expected transit start time and continued until one hour after the expected transit end time. For example, a two-hour transit duration would require four hours of continuous observation.

This greatly restricted potential targets because the entire transit must occur during nighttime hours, the weather must remain clear during that window, and the telescope must be available. Image exposure times and binning were individually adjusted for each transit event to give a maximum pixel value for the primary star between 20,000 to 40,000 and a signal-to-noise ratio over 100. We used a V filter for all images. Typical exposure times were between 30 to 60 seconds. For observations that lasted a few hours, this resulted in hundreds of individual images of the primary star. The American Association of Variable Star Observers (AAVSO) Variable Star Plotter tool was a useful resource for finding reference stars of constant magnitude in our transit’s field of view. These reference stars were used in our data analysis to compare the relative brightness of the target star in each image.

We used the software MaxIm DL to calibrate and take photometric measurements of each image. Images were calibrated with the appropriate dark, flat, and bias frames. The “Photometry” function in MaxIm DL was used to make our photometric measurements. It was necessary to identify the appropriate target, reference, and comparison stars before running our analysis. For the hundreds of images in each transit observation, MaxIm DL generated a single graph and data table that we exported into Excel to isolate the JD (Geocentric, UTC), brightness (magnitude), and error values. This information could then be uploaded into the ETD for model data fitting, which is how we determined our measured transit duration and depth. We compared our values with the expected values provided by the ETD, as well as measurements reported by other observers on the ETD to verify whether our telescope accurately observed the transit.

RESULTS

Because of complications and restrictions with telescope availability and weather conditions, we were only able to successfully observe complete transits for four exoplanets (results summarized in Table 1).

Table 1. Depth and duration results for three transits				
Exoplanet name	Depth (mag)		Duration (min)	
	Fit results	ETD value	Fit results	ETD value
Tres-3 b	0.027±0.002	0.0291	73 ± 4	77.4
Hat-P-36 b	0.022±0.001	0.0204	148 ± 4	132.9
XO-2 b	0.036±0.005	0.0124	260 ± 10	162
Wasp-48 b	0.0125±0.0007	0.0108	192 ± 5	191

This table compares our results after data fitting to values recorded in the ETD database.

An example of one of our light curves is provided in Figure 3 for exoplanet Tres 3 b. Figure 4 provides an example of the results given by the ETD after we model fit our data for exoplanet Hat-P-36 b.

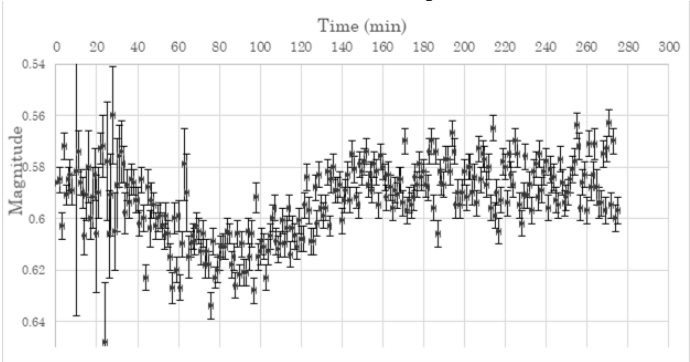


Figure 3. Light curve of Tres 3 b. Note that a higher magnitude is actually a lower observed brightness for the star. The lead time before the transit was about 30 minutes.

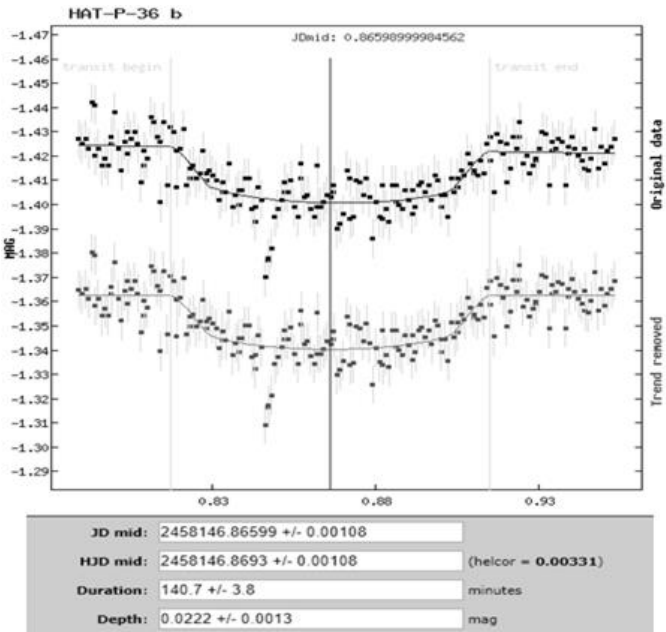


Figure 4. Screenshot of the results obtained from the ETD after fitting our data for the transit Hat-P-36 b. The ETD fitting algorithm provided information regarding transit duration and depth.

DISCUSSION

Results for transits Tres-3 b, Hat-P-36 b, and Wasp-48 b were comparable with ETD expected values, as seen in Table 1. Additionally, our results were within the range of values reported by other observers that were given a ranking of “best” according to the ETD. Tres-3 b observations ranged from 0.025 to 0.029. Values for Hat-P-36 b ranged from 0.017 to 0.022 and values for Wasp-48 b from 0.0105 to 0.0148. This confirmed that our data collection and processing methods were effective and accurate. The transit of XO-2 b was our first attempt at a transit observation with a depth below 0.02. However, our measurements of XO-2 b did not compare with the expected values from the ETD, nor were they within the range of observations reported by others on the ETD. There are a few potential reasons for why these results deviate from the expected values.

Measurement of the XO-2 b transit was difficult because of weather. On the night of the observation, there was wind and cloud coverage in Great Basin National Park. Dust kicked up from the wind, and clouds moving across our target star caused a lot of variation within the atmosphere and our data images. We were unable to model fit our data because our photometry measurements were inconsistent. We attempted to make a second observation of the transit on another night. The weather was slightly improved but still not ideal. We were able to model fit our data, which is presented in Table 1, but our results were not consistent with expected values. The variation in atmospheric conditions may be one reason why our observed depth is much larger than the averages reported in the ETD.

Additional complications were presented during the data processing of XO-2 b. The target star is in close proximity to a variable star within our frame. This was a concern for the photometry when selecting the correct aperture diameter in MaxIm DL. We needed to encircle the entire target star without including a portion of the variable star. The position of the target star relative to the variable star was not ideal. In future observations we verified beforehand that the primary star was reasonably clear of interference from nearby stars.

Given that our telescope is located in the dark skies of Great Basin National Park, we believed a 27-inch Planewave CDK 700 should be capable of measuring transits with depths around 0.01. To verify this, we observed the transit of Wasp-48 b, which had a similar depth as XO-2 b. The weather conditions during this observation were much improved, and we successfully verified a transit depth of 0.0125 ± 0.0007 .

CONCLUSION

We have verified, for the first time, that the GBO is capable of observing transits with depths greater than a magnitude of 0.01. This is shown by our results of Tres-3 b, Hat-P-36 b, and Wasp-48 b. This knowledge will help future GBO researchers when they begin exoplanet transit research. Additional observations of transits with depths lower than 0.01 can be performed to continue the characterization of the GBO for exoplanet transits.

ACKNOWLEDGMENTS

We acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research. We also thank Paul Gardner with Observatory Systems and Cameron Pace from Southern Utah University for their help in our learning to operate the GBO and in conducting the data reduction and analysis.

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Dark Sky Compliance: Measuring the Effectiveness of Outdoor Lighting Ordinances in Ogden Valley

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Abstract

Urban sky glow, or the artificial brightening of the night sky over inhabited areas due to excessive or inefficient outdoor lighting, has many negative impacts in Utah's local environments, including the disrupting of ecosystems, energy waste, and dimming residents' views of the night sky. Communities around Utah, including Weber County's Ogden Valley, are beginning to enact outdoor lighting ordinances to mitigate the impacts of this type of light pollution and conserve the dark night sky. However, it is still unclear how effective these lighting ordinances are in practice. In this paper, we aim to measure the impact of the Ogden Valley Dark Skies Ordinance, which was recently enacted in August 2017. Through a detailed inventory of commercial properties in the Ogden Valley, we are able to measure and map outdoor lights and signage that is in violation of the new ordinance. The purpose of this initial inventory is to establish both the methodology for the inventory and to capture the

baseline of compliance at the time Weber County enacted the Dark Sky ordinance. Later field work will use the same methodology to measure the effectiveness of the Dark Sky ordinance in reducing the number of noncompliant commercial properties in Ogden Valley. Both the methodology and the results of this research can help other communities around Utah measure the effectiveness of outdoor lighting ordinances, and thus establish local policy solutions to light pollution.

Light pollution is broadly defined as unwanted, excessive, or inappropriate outdoor artificial lighting. The International Dark-Sky Association (IDA), a leading nonprofit group dedicated to reducing light pollution, more specifically defines light pollution as “any adverse effect of artificial light, including sky glow, glare, light trespass, light clutter, decreased visibility at night, and energy waste” (International Dark-Sky Association 2012, 4). Four different types of light pollution are important for understanding the scope of the light pollution problem. Light trespass, when light falls where it is not wanted, is not only a sign of wasted light, but can also be a source of conflict among neighbors. Glare comes from excessive brightness that causes visual discomfort. Glare is a significant safety issue since poorly designed lighting can impact the ability of older people, whose eyes do not recover as quickly from being exposed to bright light, to see while driving at night. Light clutter is often found in urban areas that have many light sources grouped together in confusing patterns (IDA 2012).

Light trespass, glare, and clutter all represent inefficient lighting and all contribute to the fourth type of light pollution—sky glow. Sky glow, or the brightening of the night sky over inhabited areas, can obscure all but the brightest stars in the night sky—thus robbing humans of the opportunity to view all of the stars in the night sky. Sky glow is a result of inefficient lighting from artificial lights such as street lamps, porch lights, stadium lighting, or any other outdoor lighting fixtures. According to IDA, less than 20% of the lumens emitted actually provide light in the intended area. The rest of the light goes skyward, wasting energy and causing light pollution (IDA 2012).

Each type of light pollution can have significant impacts on human health and safety as well as other wildlife and the environment. Accordingly, the issue of light pollution is receiving significantly increased attention within the last few years with documentaries, popular press articles and new books (Cheney 2011; Klinkenborg 2008). Ongoing academic research is also making connections between the loss of the dark night sky and negative effects on human circadian rhythms which compromise human health and immune functions (Haim and Portnov 2013;

Chepusiuk 2009). Moreover, the loss of the dark night sky is shown to have negative ecological impacts through its influence on animal and insect breeding and migration patterns (Rich and Longcore 2005; Gaston et al. 2012; Tuxbury and Salmon 2005; Perkin et al. 2014).

Human health and ecological challenges are amplified by the economic costs of light pollution. Research suggests that up to one third of all lighting in the United States is wasted. Globally, outdoor electric lighting makes up 8% of global energy use, with about 60% of that being wasted through unneeded, overlit, or poorly-aimed lighting (IDA 2013). In the United States, estimates suggest that light pollution costs nearly \$7 billion annually, when the costs of wasted energy and the costs of mitigating the impacts on wildlife and health are taken into account (Gallaway et al. 2009). Individuals and city governments inevitably pay the costs of overlighting the night (Henderson 2010).

In theory, light pollution should be relatively easy to manage. The solution is simply to make more efficient use of lights by pointing them toward the ground and shielding them so that the light is usable. In practice, as you might expect, efforts to preserve the night sky have been more complex. Innovative lighting practices and strategies can help home owners, business owners, and municipalities reduce light pollution, but in practice, as you might expect, efforts to reduce light pollution have been more complex.

To accomplish a sustained reduction of light pollution and conservation of the dark night sky, particularly in an urban setting, planning and community effort are essential. The IDA recognizes the importance of local policy and publishes a Model Lighting Ordinance that is designed to “develop outdoor lighting standards that reduce glare, light trespass, and sky glow” (IDA 2014). Having access to an effective model ordinance is not enough, though, as local governments, planners, citizens have differing needs and interests in relation to the night sky.

Communities around the world are beginning to enact outdoor lighting ordinances to mitigate the impacts of this type of light pollution and conserve the dark night sky. Communities can plan for eliminating light pollution to enhance public safety, protect private property rights, reduce electricity consumption and lower city costs, maintain consistency in exterior lighting applications, reduce neighbor-to-neighbor complaints, and improve community aesthetics and quality of life. Among other things, these codes can regulate hours of operation, maximum illumination levels, amount of required shielding, color temperatures, light trespass, and the characteristics of illuminated signs. Increasingly, communities around the United States are beginning to implement dark sky ordinances. This is particularly true in the high-amenity

places of the American West such as the Ogden Valley, a planning district in Utah's Weber County.

The Ogden Valley Lighting Ordinance was enacted in August 2017 and outlines compliance measures for outdoor lighting with the intent to preserve the character of the night sky. The Ogden Valley Lighting Ordinance dictates that any new residential or commercial structures built after the ordinance took effect in 2017 require approval of all outdoor artificial light sources. For already existing commercial property, outdoor lighting must be in compliance with the ordinance within 10 years. Importantly, lighting standards are not mandatory for single-, two-, or three-family dwellings in existence or approved on or before August 1, 2017. The ordinance also provides photo references to illustrate fixtures that are/are not in compliance.

The Ogden Valley Lighting ordinance is a strong document that has earned the support of community members and policy makers. The ordinance is comprehensive in its coverage of outdoor lighting allowances but lenient enough so that measures required are not unreasonable. In fact, most lighting violations can be circumvented by placing motion sensor outdoor lighting so as to address potential safety issues associated with unlit spaces. As such, the ordinance is a strong forward step in policy-making oriented toward preserving our dark skies.

However, in other regards, the Ogden Valley Lighting Ordinance does not address all of the contributors to light pollution. For example, the ordinance does not apply to single-, two-, or three-family dwellings built or approved before August 1, 2017. Visual inspection shows that there are many lights that would be considered in violation, so limiting mandatory compliance to businesses will not have the magnitude of impact that mandating total compliance would have.

The ordinance is important, and in many ways should be held up as a model ordinance for other communities looking toward regulating light pollution. However, for this project, the creation of the specific policies found in the ordinance is not our primary focus. Instead, we are interested in measuring the overall impact of the policies found in the ordinance. How can we measure the impact of dark sky ordinances such as the one found in Ogden Valley? Do they have measurable impact on light pollution? Researchers have begun to look at lighting ordinances and to propose best practices for ordinances, but the impact of the ordinances are not yet understood. Communities adopt dark sky ordinances, but how effective are these ordinances at actually protecting the dark night sky? While the answers to all of these questions are beyond the scope of this research project, in this paper we aim to establish a framework for understanding the role of lighting ordinances in night sky preservation efforts.

To measure the impact of the ordinance, we have begun by creating a methodology for establishing a baseline of the current status of lights that fall in violation of the new lighting ordinance. This baseline survey, while intended to act as a baseline, has also provided a few preliminary results that we discuss later in the paper. The goal of this paper is to establish the method of our baseline survey so that we may measure the impact of the lighting ordinance by reproducing at a later time. If the number of lighting violations decreases significantly over the period between surveys, we can demonstrate the impact of the lighting survey.

Project Design

We began by reviewing the code for possible types of violations. We assigned each violation an abbreviated code to allow for quick reference. In total, we identified 24 discrete possible violations of the ordinance. Notable examples of these possible violations include: 1) If the outdoor fixture is not fully shielded and/or downward directed (with sub-categories about whether the fixture projects directly into the night sky or if the shielding material is translucent); 2) Light curfew. If the outdoor lighting is on after 10 p.m. or within one hour of close of business, whichever is later. 3) Holiday lighting that is out of season. 4) Signage. More than one illuminated window sign, sign measures more than 4 square feet or is illuminated past business hours, if the lights on the sign are not shielded or downward directed.

We created a template for the inventory that included location, date of citation, abbreviated code of violation, an explanation of the violation, whether the violation was also infringing on the light curfew, as well as the location of the violation on the property. We then worked with the Geographic Information Specialists at Weber County to identify all of the commercial properties within the survey area, including businesses, churches, schools, cemeteries, and government offices. Then, using camera, maps, inventory template, and pens, we performed the inventory during the evening in winter months after the sun went down and after business hours. At each location that registered a violation, we took photographs of the violations to support the written description of the lighting violation. The act of taking the inventory took about eight hours, and the processing of photographs and other information took approximately 15 hours of work.

Findings

We found 54 nonresidential locations that had at least one outdoor lighting fixture in violation of the Dark Sky ordinance. Properties found

in violation included one ski resort, 10 hotels or vacation rental properties, 3 gas stations, 7 restaurants, and a mixture of other schools, churches, and government buildings.

The total number of properties in violation tells only part of the story, though. The total number of fixtures in violation gives an additional insight into the scope of the current situation. Of the 678 outdoor lighting fixtures in violation, 510, or 75 percent, of those were in violation for unshielded or insufficient shielding. Thirteen percent of violations were for violations of the lighting curfew. Seven percent of violations were for lights projecting directly toward the sky. Two percent of violations were for holiday lights illuminated out of season. The other five violations made up the remaining two percent of violations, and thus are thus of relatively minimal impact.

Signage violations were not as common as other lighting violations with only 38 total violations. Of those, however, 16 (42%) were violations of light sources projecting from or beyond the sign area. Eleven (29%) of the violations were for lights that were not directed towards the ground. The remaining 29% were a mix of 4 different violation types.

The takeaway here is that most of the lighting and signage violations that we observed were for lights that were not shielded or not directed toward the ground. These problems, although most prevalent, are also very solvable. Simply replacing or retrofitting light fixtures without shields would address most of the problems with lighting in the Ogden Valley.

Between both outdoor lighting and signage, we recorded a total of 716 violations, with 678 of those being outdoor lighting violations and only 38 individual violations of the signage requirements. This means that, on average, each of the violators has 13.26 lights in violation of the ordinance. This overstates the average number of violations per property, though, as there were a handful of properties that had large quantities of violations, including one property with 140 violations, another with 113 violations, and another property with 78. If these offending properties are removed from the equation, then the average number of violations per property is 7.6, which seems like a more tractable problem. The disparity between the quantities of lighting violations on different properties highlights the important fact that most property owners that are in violation of the ordinance would only need to slightly alter their lighting strategies over the next decade—a task that may not be too onerous for many of these property owners. Higher quantity violators, however, can anticipate making more significant investments to update their lighting strategies.

Discussion

This survey highlights some important observations. By identifying the most prominent offenders, county officials and ordinance enforcers can now be strategic in their efforts to encourage commercial property owners to comply with the ordinance by the time it takes effect in 2027. Not only can code enforcers know who they should be focusing their efforts on, but they can now know what type of violations are most problematic. This information can allow officials to focus their community education and outreach efforts in a more strategic way.

Perhaps more important, however, is the fact that we have produced a baseline survey of lighting violations. The location, type, and quantity of the lighting violations will be valuable information when the inventory is repeated in 5 years and then again 5 years after that. This time scale will allow us to demonstrate the effectiveness of the lighting ordinance in limiting protecting the night sky. The inventory was not overly time-consuming and was relatively straightforward once the specific violations had been extracted from the code. Using an inventory as a method for establishing a baseline for compliance was an effective way to identify current outdoor lighting fixtures that interfere with dark skies.

There are, however, limitations to the lighting violations inventory methodology. Each violation is counted as a single violation regardless of the light output. For example, it does not discriminate between a high-output streetlight or a low-powered porch light. Therefore, there is no way to quantify how much light pollution is actually escaping into the night sky. Other methods for measuring actual light pollution, including using handheld sky quality meters, will need to be added to this methodology in order to have that valuable information.

Conclusion

Light pollution is a critical issue that is threatening the sustainability of economies, societies, and environments of our nighttime spaces in the United States. Citizens and planners in many places are beginning to use policy tools like dark sky ordinances to combat the problems of light pollution. But we don't know yet how effective these lighting ordinances are at actually limiting light pollution. Our methodology or lighting violation inventories shows promise in measuring the impact of these dark sky ordinances. As we reproduce this inventory and compare it with the findings of the baseline survey, we will be able to measure some of the impact of these types of dark sky ordinances. Taking an outdoor light inventory was a relatively straight-forward method of identifying light fixtures and signs that interfere with dark skies. This inventory can be mapped and used as a baseline in future years to monitor increasing or

decreasing compliance. Establishing a comprehensive dark skies ordinance, providing reasonable means of compliance, and undertaking a light inventory appear to be effective initial steps in establishing a policy solution to light pollution.

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Law is Politics: Why Critical Legal Studies, Critical Race Theory, and Other Critical Legal Disciplines Must Reunite

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Critical race theory (CRT) removed itself from critical legal studies (CLS) during the height of critical legal exploration because the CRT founding members claimed that CLS did not devote enough attention to racial issues. CRT's reasons for departure were laudable. CRT has every right to fight for people of color, but the complete separation has caused harm to the critical field. CRT flourished when working with ordinary people, but CLS was equipped to deal with broader injustices more effectively than CRT because CLS addresses, in addition to race, a range of disadvantaged groups. CLS focuses on race, gender, socioeconomic struggles, and more. Therefore, CRT and other critical fields are vital to the fight for equality for disadvantaged peoples. However, complete abandonment of CLS was detrimental to the overall cause of all underrepresented groups that needed critical representation. The critical legal fields must reunite to create a discipline capable of overcoming legal injustice in all its forms.

In the midst of the 2016 American presidential election, Saturday Night Live (SNL) aired its most memorable sketch of the season. More importantly, however, it served as a poignant political critique on the unnecessary separation of race in America. The black actors Kenan Thompson, Sasheer Zamata, and Leslie Jones were joined by the white actor Tom Hanks to play “Black Jeopardy.” The fictitious gameshow is usually a humorous skit that plays on the idiosyncratic features of black Americans. However, on this particular occasion, SNL writers made a stronger point. On October 22, 2016, Hanks played Doug, a lovable Donald Trump supporter turned game show contestant. Doug speaks with a rural twang and his attire consists of a bald eagle shirt and a red “Make America Great Again” trucker hat.

Tension between the contestants exists during the first few questions between black and white contestants, but Doug’s answers coincide with “black answers.” The concern among the diverse contestants slowly disperses as they realize they share similar views. SNL presents an idea that so many critical theorists have neglected, namely, poor uneducated people share commonalities regardless of skin color. SNL solidifies its critique when the Final Jeopardy question demonstrates how partisan issues continue to divide like-minded people with the divisive final topic, “Lives That Matter.”¹

This paper begins by exploring the emergence of critical Marxist thought generally. It proceeds to detail the beginning of the critical legal studies (CLS) movement. Following this commentary, it describes critical race theory’s (CRT) intellectual break from CLS followed by the history of CRT’s movement and its justification for fracturing with CLS. Finally, this paper concludes that CLS, CRT, and other critical disciplines should reunify to form a more comprehensive movement that serves more disenfranchised people.

Marxism’s Base and Superstructure

Marxism, the forerunner to CLS, CRT, and all critical scholarship, necessitates a brief explanation of a few key terms. Karl Marx, the father of critical theory, argued that people are best understood through an economic and historical lens. This comprises part of Marx’s theory of historical materialism, which is based on the theory that the history of peoples is best understood through economic conditions. Therefore, plebeians in ancient Rome are best comprehended by studying Rome’s

¹ “Black Jeopardy with Tom Hanks.” NBC. Accessed March 14, 2018, at <http://www.nbc.com/saturday-night-live/video/black-jeopardy-with-tom-hanks/3333590?snl=1>.

slave economy. Similarly, medieval serfs are best understood by studying a feudal system. Thus, Marx argues that we do not use social interaction to grasp the workings of society; instead, we understand society through its struggle for material wealth.²

According to Marxism, class struggle motivates all change (for good or ill).³ In the *Communist Manifesto*, Marx plainly states, “[t]he history of all hitherto existing society is the history of class struggles.”⁴ Marx determined that class struggle has always existed over material goods, and until the proletariat arises, it always will. Therefore, balance of economic assets is vital among socioeconomic groups because that is the only way class struggle will end.⁵

Marx’s concept of superstructure and base is particularly relevant for understanding a major difference between CRT and CLS. The base is the component of society that generates material wealth, such as ordinary workers, machinery, and other forms of the means of production. Comparatively, the superstructure consists of law, religion, politics, and ideologies.⁶ It consists of formal methods that legitimate exploitation of the base. The superstructure rests atop the base, which led Marx to argue that for the superstructure to have any substantial change, the base must move it.⁷ As an example, it is likely that Marx would have approved of Egypt’s mass upheaval in 2011 because the people (base), not the law (superstructure), wrought the change. The law only augmented popular force following the revolution.

Critical Legal Studies

CLS was born from Marxism and the Frankfurt School’s critical theory. CLS advocates, otherwise known as Critics, formed CLS as an academic movement and a loosely knit organization of legal scholars.⁸ CLS adopted Michel Foucault’s version of power and power relations. Critics extensively integrated his writings into much of their work, but his major contribution to CLS was his theory that the legal system had a repressive

² See *Communist Manifesto* and *Economic and Philosophic Manuscripts of 1844*.

³ Kath Woodward, *Social Sciences the Big Issues* (Abingdon, Oxon: Routledge, 2014), 84.

⁴ Karl Marx and Friedrich Engels, *The Communist Manifesto*, ed. Frederic L. Bender (New York, NY: W.W. Norton & Co., 2013), 55.

⁵ Isaak I. Rubin, *Essays on Marx’s Theory of Value* (India: HarperCollins, 2007), 100.

⁶ Stephen H. Rigby, *Marxism and History: A Critical Introduction* (Manchester: Manchester University Press, 1999), 176-77.

⁷ William R. Schroeder, *Continental Philosophy: A Critical Approach* (Malden, MA: Blackwell, 2005), 67.

⁸ Harvey J. Kaye, “British Marxist Historians,” in *A Dictionary of Marxist Thought*, ed. Tom Bottomore (Oxford: Blackwell, 2006), 61.

effect on already oppressed communities.⁹ This doctrine became one of the core principles of CLS. Critics continued publishing along lines that followed the Foucauldian argument of an oppressive legal system. To this end, Critics focused on power's oppression upon helpless classes. CLS contends that these unprotected people share the common trait of living in crippling poverty. Thus, CLS seeks to improve the socioeconomic world of all downtrodden individuals regardless of classification. Critics rallied around common themes such as (1) indeterminacy of the law, (2) a dismissal of traditional forms of legal ideas—most importantly individual rights, and (3) a “countercultural sensibility” that focuses on exposing how law legitimizes the dominant social interest.¹⁰ CLS ideology can be viewed as a byproduct of its belief that “law is politics.”¹¹ Comprehensively, CLS aims to liberate downtrodden groups from oppression through legal methods. CLS's ultimate goal is to rectify the inequality of power within the legal system.

The first tenet of Critics' critical technique of systemically burdensome law comes from their tenet on indeterminacy of law. Indeterminacy originated in response to the movement of scientific legal thinking, where jurists viewed law as a science that, if properly applied, routine outcomes would regularly result. Legal scientists adhered to the maxim, “law works itself pure.”¹² Critics refuted this idea based on rule and counter rule. When equally important rules contradict each other, a policy analysis ensues and a balancing act of rules is the result.¹³ To Critics, it was absurd to think that all judges would reach the same outcome with the same set of facts. Critics claimed that this ideology discounted the human nature of legal decision makers that ultimately had varying passions and inherent biases.

Second, in conjunction with legal indeterminacy's balancing requirement, the critique of individual rights is a central component of CLS. While rights have many definitions, for this paper, Critics major critique of rights align most closely with individual rights. The Critics' negative view of rights came from a criticism of liberal constitutionalism

⁹ Peter Goodrich, “Sleeping With the Enemy: An Essay on the Politics of Critical Legal Studies in America,” *N.Y.U. Law Review* 68, no. 2 (May 1, 1993): 402.

¹⁰ Pierre Schlag, “Critical Legal Studies,” in *The Oxford International Encyclopedia of Legal History*, ed. Stanley N. Katz (Oxford: Oxford University Press, 2009), 295.

¹¹ Mark Tushnet, “Critical Legal Studies: A Political History,” *Yale Law Journal* 100, no. 5 (March 1, 1991): 1517.

¹² Ronald Dworkin, “Law's Ambitions for Itself,” *Virginia Law Review* 71, no. 2 (1985): 173-187, doi:10.2307/1073016. Refers to this ideas as “old-fashioned and silly.”

¹³ Mark Tushnet, “Survey Article: Critical Legal Theory (without Modifiers) in the United States,” *Journal of Political Philosophy* 13, no. 1 (March 2005): 99-100, doi:10.1111/j.1467-9760.2005.00215.x.

that pervaded legal academia throughout the Sixties and Seventies. Scholars pointed towards the acquisition of individual rights to show triumph of liberal democracy over racism and bigotry. Preeminent Crit, Duncan Kennedy, questions whether the long-held notion that this period was a success in terms of increased freedom and equality is accurate. Derrick Bell, a founding member of CRT, theorized interest convergence theory, which argues that minorities only acquire rights from the dominant portion of society when gains by people of color are automatically triggered when dominant interests are intentionally furthered.¹⁴ An individual, fundamental right denotes that it transcends general legal analysis. A right has a privileged status. Critics use this core belief of rights as an attack against law's constancy. Like the indeterminacy of law, rights often contradict each other. For example, when the Second Amendment interferes with the fundamental right to life or property, a strategic assessment occurs. Rarely is there a way to determine which abutting right is inherently more fundamental than the other, thus a policy analysis is required. Consequently, in the United States federal system, 9 presidentially appointed justices daily engage in the same process that 535 democratically elected legislators are elected to perform. The major difference is that legislators are theoretically required to answer to constituents, while 9 members of a body that are largely unrepresentative of the American people, not only have the same power, but often overrule the 535 Congressional members.¹⁵

Indeterminacy within the law led Critics to criticize law's characterization as pure truth as long as contradictory areas within the law existed. Because of the law's inability to consistently determine the same correct answer, legal ambiguities empowered judges to manipulate the law in reaching decisions they always desired. Because of the uncertainty of law, Critics deemed that social policy ought to be openly considered in legal decisions. Imprecise law generates more conflict within legal and political institutions. This dilemma could be mitigated by adding an additional interpretive tool to legal decision-makers' arsenal. Without this adjustment, uncertain outcomes induce a common Marxist critique concerning the superstructure and base. A conflict arises between the legal institution and the individual, which is inherent in legal indeterminacy.¹⁶

¹⁴ Derrick A. Bell, "Brown v. Board of Education and the Interest-Convergence Dilemma," *Harvard Law Review* 93, no. 3 (1980): 518-533, doi:10.2307/1340546.

¹⁵ Duncan Kennedy, "The Critique of Rights in Critical Legal Studies," in *Left Legalism/Left Critique*, ed. Wendy Brown and Janet Halley (Durham, NC: Duke University Press, 2003), 222-24.

¹⁶ Stephen Waddams, *Dimensions of Private Law Categories and Concepts in Anglo-American Legal Reasoning* (Cambridge: Cambridge University Press, 2003), 205.

The conflict arises between the two groups because law rarely produces a uniform outcome for all offenders.

Third, CLS contends that the indeterminacy of rights, which purportedly are in place to protect the less advantaged, empowers law to legitimate social domination. Law represents power. That power is used by the class that controls the superstructure, and therefore the law is used to bolster the powerful's prevailing hold on society. Robin West, scholar on authoritarian regimes, argues that celebration of law without questioning or criticizing it leads to oppression and subjugation.¹⁷ CLS seek to criticize and analyze the structure of power within the legal system. Therefore, Crits perform the necessary service of staving off oppression for those that are incapable of preventing it themselves.

In addition to formal legal institutions, Crits challenged legal education. Law students entered law school as left-leaning liberals. At a minimum, legal education depoliticized the legal neophytes. At worst, students were fundamentally conservatized through traditional forces in legal academia. Conservatism was instilled into the students through course selection because more doctrinal classes were offered at the expense of removing theoretical courses to provide funding for apolitical courses.¹⁸ Unfortunately, this pedagogical mistake created fewer scholars and more practitioners that were unable to critically analyze law.

Not only were law students falling behind in critical inquiry, Crits claimed that fellow academics were failing too because they resorted to a soft, noncritical inquiry of the law.¹⁹ Legal academics chose to support legal institutions rather than instigating changes by asking difficult questions. Crits reproved individual academics for bad faith because their legal examination lacked critical methods, thereby legitimizing institutional authority that disregarded the oppressed class.²⁰ Legal academia did not receive CLS's message very warmly; after all, nearly the entirety of legal academia was being questioned. Furthermore, Crits contended that without proper critical mentorship, many law students would become legal nihilists as they discovered legal inconsistencies. CLS wanted to be a safety net for these students rather than letting them completely lose faith. Roberto Unger recounts the anger students felt toward

¹⁷ Robin West, *Narrative, Authority, and Law* (Ann Arbor, MI: University of Michigan Press, 2001).

¹⁸ See James B. White, "Doctrine in a Vacuum: Reflections On What a Law School Ought (and Ought Not) To Be," *Journal of Legal Education* 36, no. 2 (June 1, 1986): 159.

¹⁹ Carrie Menkel-Meadow, "Feminist Legal Theory, Critical Legal Studies, and Legal Education or 'The Fem-Crits Go to Law School,'" *Journal of Legal Education* 38, no. 1-2 (Spring 1988): 70.

²⁰ Lewis R. Gordon and Jane Anna Gordon, *A Companion to African American Studies* (Oxford: Blackwell, 2004), 335.

their professors as they discovered legal inconsistencies when he wrote, "“When we came, [law professors] were like a priesthood that had lost their faith and kept their jobs. They stood in tedious embarrassment before cold altars. But we turned away from those altars and found the mind's opportunity in the heart's revenge.”"²¹

Among the many strengths of CLS, its main contribution toward reunification of the critical legal disciplines (“disciplines”) would be its high level of inclusivity. Prominent Crit Robert Gordon stated:

We would like our work ... to help in modest ways to realize the potential we believe exists to transform the practices of the legal system to help make this a more decent, equal, solidary society—less intensively ordered by hierarchies of class, status, “merit,” race, and gender—more decentralized, democratic, and participatory both in its own forms...²²

CLS’s framework was established around attacking the conservative legal establishment in hopes of obtaining comprehensive advocacy. To achieve this goal, Crits sought to rectify legal injustices in all forms. They viewed legal oppression as a product of the American judicial system that included judges, lawyers, and most disturbingly to Crits, legal scholars. Crits adopted Marxist theory as a catalyst for social improvement. They notified the legal community of the injustices and oppression it perpetuated against all ensnared by poverty. While CLS never completely realized its goal, it has become an impetus for several disciplines. Because of the activity of the Crits, legal academia still holds onto some hope of creating a better world for the oppressed classes.

Critical Legal Studies Criticisms

Paul Carrington, one of CLS’s most avid critics, characterized CLS as mere nihilism. Carrington’s definition of nihilism stems from his erroneous belief that Crits completely disregard law.²³ He fails to validate his claim, offering only the Tinkerbell effect as evidence—if there is no belief in the legal system it will fail. Belief in the current system is irrelevant for Crits because their methodology is critique, not solution. Crits

²¹ Roberto M. Unger, *The Critical Legal Studies Movement* (Cambridge, MA: Harvard University Press, 1986), 119.

²² Robert W. Gordon, "Unfreezing Legal Reality: Critical Approaches to Law," *Florida State University Law Review* 15, no. 2 (Summer 1987): 197.

²³ Paul D. Carrington, "Of Law and the River," *Journal of Legal Education* 34, no. 2 (June 1984): 227.

pave the way for reform by exposing illegitimate legal practices. The legal community can only fix systemic oppression after weaknesses are exposed. Crits perform the necessary analytical precursor prior to obtaining the finished product. Carrington fails to discern that a desire to change the legal system does not result in aggression to *all* legal systems.

In an argument of a similar vein, opponents criticize CLS for employing legal empiricism. These critics define empiricism as investigating law through social inquiry, surveys, studies, and other analyses.²⁴ However, the critique is subtly bolstered by more than just a basic understanding of empiricism. Rather, these critics understand law as a naturally occurring phenomenon, namely, that it can be discovered by repetitious study. Crits do not shy away from this criticism, instead declaring, “of course we are empiricists!” CLS stands for remedying the wrongs that the legal system created, so of course, Crits ventured outside of pure law. To correct past legal abuse, Crits applied empirical methods to discern legal injustice so as not to be prejudicially troubled by the law itself.

CLS’s most deserving criticism is on grounds of paternalism. CLS’s goal to build “a left bourgeois intelligentsia that might one day join together with a mass movement for the radical transformation of American society” is inherently paternalistic.²⁵ However, CLS has never conjured anything near a mass movement. By distancing itself from legal liberalism, CLS rejected the base’s support. Critical race theorist Patricia Williams allegorized Crits to Gods on high that played games with words while the lower class saw no benefits from the Gods’ fruitless games.²⁶ Kennedy assumed that if it was not for their benevolence, “It [would be] unlikely that a mass movement could ever be permanently successful in the United States.”²⁷ Unifying with CRT, along with adopting their groundwork methods, would discharge much of CLS’s paternalism. As Crits start seeing ordinary people as allies instead of charges, it could implement what they only have flirted with—motivating the populace for a significant mass upheaval.

²⁴ David M. Trubek, “Where the Action Is: Critical Legal Studies and Empiricism,” *Stanford Law Review* 36, no. 1/2 (January 1984): 575-622, doi:10.2307/1228692.

²⁵ Mike Cole, *Critical Race Theory and Education: A Marxist Response*, 2nd ed. (New York, NY: Palgrave Macmillan, 2017), 14.

²⁶ Patricia J. Williams, “Alchemical Notes: Reconstructing Ideals from Deconstructed Rights,” in *Critical Race Theory: The Cutting Edge*, ed. Richard Delgado and Jean Stefan-cic (Philadelphia, PA: Temple University Press, 2013), 97-98.

²⁷ Duncan Kennedy, “Legal Education and the Reproduction of Hierarchy: A Polemic against the System,” *Journal of Legal Education* 32, no. 4 (December 1, 1982): 610, doi:10.2307/1288698.

Many critiques have been leveled against CLS. Most have been unfounded, and many more have shown a misunderstanding of the movement. CLS, although fading in the past few years, still has an enduring legacy of championing victims of the maldistribution of power. While CLS is much less cohesive than it once was, critical thought process has spread from the discipline into numerous aspects of legal studies, education, sociology, and other scholarly thought. Reunifying disciplines would reanimate CLS, making it a group capable of action instead of just critique and theory.

Critical Race Theory

CRT was born in the 1980s from several legal scholars' frustration with CLS. At a CLS conference in Los Angeles in 1987, critical race theorists were given the floor to express their irritation with CLS's treatment of people of color. However, most of CRT's dissatisfaction with the legal establishment mirrored CLS's frustrations. Indeed, both groups agree that law is a social phenomenon, not a purely objective concept.²⁸ Primarily, critical scholars diverge over the issue of race. They still share views on many topics.

CRT traces its roots back to legal liberalism. Furthermore, CRT developed from activism during the civil rights era. Kimberlé Crenshaw, an esteemed critical race theorist, stated "liberal reform both transforms and legitimates" the law.²⁹ Whereas CLS refused to acknowledge legal liberalism, most of CRT initially memorialized it. This memory increased support for the base among CRT.³⁰

The entire civil rights movement's history need not be recounted here, but it is important to note that many minority leaders in the legal field spawned from the civil rights movement. The legal activist Charles Hamilton Houston improved the National Association for the Advancement of Colored People (NAACP) by training the legal team that was responsible for the controversial *Brown v. Board of Education* decision.

²⁸ Pierre Schlag, "Critical Legal Studies," in *The Oxford International Encyclopedia of Legal History*, ed. Stanley N. Katz (Oxford: Oxford University Press, 2009), 299.

²⁹ Kimberlé Williams Crenshaw, "Race, Reform, and Retrenchment: Transformation and Legitimation in Antidiscrimination Law," *Harvard Law Review* 101, no. 7 (May 1, 1988): 1370, doi:10.2307/1341398.

³⁰ Henry Louis Gates, "Good-bye, Columbus? Notes on the Culture of Criticism," *American Literary History* 3, no. 4 (Winter 1991): 721, doi:10.1093/alh/3.4.711. It is important to know that although CRT traces its lineage back to the liberal rights movement, they have since distanced themselves from the movement as did CLS.

³¹ At the time, *Brown* was considered to be a major victory for the African-American community. Surely, these oppressed people assumed their oppression was coming to an end.

However, the injustice did not cease. Prejudice, institutionalized racism, and various inequalities continued after the *Brown* decision. Schoolwide integration was nowhere near realization. Because of the lack of progress, some critical race theorists drifted away from legal liberalism. Lewis M. Steel, a prominent NAACP member and critic of legal liberalism, was fired from his NAACP position on account of his vocal criticism that *Brown* benefited whites more than blacks.³² Similarly, Derrick Bell, known as the “intellectual father figure” of CRT, criticized the liberal movement for enacting change that was ultimately harmful to people of color. Instead, Bell argued, the result was a mere interest convergence. Interest convergence occurs when the dominant race’s interest and the minority’s interests converge. The benefit to people of color is incidental and only results when their interest overlaps with the dominant race’s interest.³³

CRT quickly determined that race is the inequality most demanding of redress in America’s legal system, and therefore, it needed to be critical theory’s vanguard. Bell emphasized that the most fundamental element of American legal jurisprudence rests on race. Moreover, he contended that law throughout American history has been designed to subordinate black people to whites.³⁴

CRT hit its stride during the conservative Reagan period. Conservative rhetoric developed the ideology that the civil rights movement had done its job, eradicating racism and prejudice. Conservatives argued that once overt racism was removed, racism would no longer be a significant issue. Critical race theorists strongly refuted this theory by citing implicit bias. Crenshaw argued that race-conscious motivation still exists underneath the surface of American jurisprudence, and because of those implicit biases, CRT is necessary.³⁵

Likewise, CRT contributed to American thought through the concept of cultural pluralism. This doctrine argues that race should be

³¹ Richard A. Fairfax, Jr., “Wielding the Double-Edged Sword: Charles Hamilton Houston and Judicial Activism in the Age of Legal Realism,” *Harvard BlackLetter Journal* 14 (Spring 1988): 24.

³² Marc Seitles, “The Perpetuation of Residential Racial Segregation in America: Historical Discrimination, Modern Forms of Exclusion, and Inclusionary Remedies,” *Journal of Land Use & Environmental Law* 14, no. 1 (October 1, 1998): 89-124.

³³ Bell, *Brown v. Board*, 518

³⁴ *Ibid.*

³⁵ Crenshaw, *Race, Reform, and Retrenchment*, 1370.

acknowledged and examined. Pluralism contends that people should embrace racial differences, not hide from them. Racism can only be removed if it is acknowledged as a routine part of life. Cultural pluralism allows people of color to experience their unique struggle without being overwhelmed by dominant culture.³⁶

Moreover, CRT presented the concept that ascendancy serves white elites and working-class people, and because it requires careful scrutiny, only blatantly racist inequalities are being fixed. Ascendancy complements Bell's interest convergence theory. Occasionally, changes occur that appear to retract racism, but the motives behind the changes are not altruistic. Instead, white interests are being advanced, and people of color's interests just happen to coincide.³⁷ This results in a gain for whites and a mollification of minority dissatisfaction. This pacification inhibits true growth against racism because scholars, such as Peter Wood, point to improvements in the legal system as proof that racism no longer exists.³⁸

CRT also championed the idea that race is a social construct. There is nothing genetic that causes race.³⁹ Race is something that society alters or even removes when it is beneficial to the dominant society. This can be viewed as the initial hatred displayed towards Italian and Irish immigrants. However, after a period of hatred, these groups have been assimilated into white culture, and they are now white.⁴⁰ Although there could be a dispute as to the actual genetic makeup, there can be little dispute as to whether sociological functioning is created, at least in part, by racism and social surroundings. This may be CRT's strongest contribution to understanding racism.

Additionally, CRT claims that racial minorities can serve as effective scapegoats. Scapegoats are a method whereby weaker groups or individuals are used to discharge social ills and pains caused by the dominant class. Thus, the scapegoat is a ritualistic sacrifice made by society in hopes of restoring its illusory health. In 1941, Louis Wirth stated:

³⁶ Ahmed Gurnah, "The Politics of Racism Awareness Training," *Critical Social Policy* 4, no. 11 (1984): 6, doi:10.1177/026101838400401102.

³⁷ Bell, *Brown v. Board*, 518.

³⁸ Peter Wood, "Bell Epouque," *The Chronicle of Higher Education*, March 13, 2012. Accessed May 01, 2018, at <https://www.chronicle.com/blogs/innovations/bell-epoque/31897>.

³⁹ Noah A. Rosenberg, "Genetic Structure of Human Populations," *Science* 298, no. 5602 (December 20, 2002): 2381-2385, doi:10.1126/science.1078311.

⁴⁰ Irish: Noel Ignatiev, *How the Irish Became White* (New York, NY: Routledge, 2009). Italian: Jennifer Guglielmo et al., *Are Italians White? How Race Is Made in America* (New York, NY: Routledge, 2003).

For those who feel themselves threatened in the continued enjoyment of their power and security a minority serves as a convenient scapegoat toward which mass indignation can be diverted. Similarly, for those who have been frustrated in their ambitions or who have already become declassed, the minority group furnishes a rationalization of their own inadequacies and an object toward which they can release their pent-up emotional drives for aggressive self-assertion.⁴¹

CRT analogized this ancient biblical practice of discharging Israel's sins to the unwarranted marginalization that people of color routinely received as they were "sacrificed." Scapegoating is practiced when white elite and white working-class Americans briefly ally to disparage Latina/os as the cause of America's woes. Through this sacrifice, white elites maintain power by diverting the economic and social ills to Latina/os, in particular Mexican immigrants. The working class white does not stand to gain from the scapegoat in any real sense but become ideologically convinced that life will improve for them. The result is SNL's Black Jeopardy where people agree, but an artificially constructed idea is used to separate them.

CRT utilizes the base like no other academic group does. This has been its largest contribution to the critical legal field. However, CLS was overly paternalistic, causing them to neglect ordinary people in favor of impacting the superstructure. They became obsessed with the power of law had over the base. They believed an altered base would stop oppression. This was a total break from Marxist thought. Marx focused on changes in the base. Only then would the superstructure shift because it was situated atop the base. This deficiency leads to the warranted attack on CLS's paternalism.

CRT's actions with the base would have been a major benefit to the entire discipline. CRT has done a phenomenal job at working with the base. This most likely occurs because of CRT's ancestor in the civil rights movement. Not only have critical race theorists learned to interact and modify the base, they have grown proficient at altering the superstructure. Any student of Marx should be impressed by CRT's synthesis of modifying the base and superstructure for the benefit of oppressed people.

⁴¹ Louis Wirth, "Morale and Minority Groups," *American Journal of Sociology* 47, no. 3 (1941): 423, doi:10.1086/218921.

Critical Race Theory Criticisms

Scholars of other disciplines have challenged CRT for creating a black-white binary power system. In an effort to attract attention to black plights, CRT has minimized other racial minorities. Juan F. Perea, and other critical race theorists, have acknowledged this mistake.⁴² Other CRT scholars are attempting to remove the black-white binary stigma, while still others are opening CRT to smaller critical groups like LatCrit and AsianCrit.^{43,44}

The most enduring criticism that CRT faces is its exclusivity. Not only does CRT limit its work to people of color, but leaders have been territorial in protecting the upper echelons of CRT leadership. Professor Richard Delgado argued that white critical scholars should never take a leadership role in CRT because they lack the life experiences of abuse required to fulfill such a task.⁴⁵ Alan Freeman, a prolific white critical race theorist, replied,

My whiteness is of course an inescapable feature, [but] I have tried hard to listen, to understand, to gain some empathetic connection with victims of racist practice. I have no illusion of having crossed an uncrossable gap; yet I believe I can make a contribution. It is true that I am not compelled by color to participate in this struggle; I could stop any time, but I haven't.⁴⁶

Freeman does not deny Delgado's assertion that he cannot completely understand people of color's viewpoint. In fact, he agrees that it is an "uncrossable gap." However, he offers an alternative reason why white scholars should be heavily involved in CRT. Freeman contends

⁴² Juan F. Perea, "The Black-White Binary Paradigm of Race," in *Critical Race Theory: The Cutting Edge*, ed. Richard Delgado and Jean Stefancic (Philadelphia, PA: Temple University Press, 2013).

⁴³ Roy L. Brooks and Kirsten Widner, "In Defense of the Black-White Binary: Reclaiming a Tradition of Civil Rights Scholarship," in *Critical Race Theory: The Cutting Edge*, ed. Richard Delgado and Jean Stefancic (Philadelphia, PA: Temple University Press, 2013).

⁴⁴ Alison Crump, "Introducing LangCrit: Critical Language and Race Theory," *Critical Inquiry in Language Studies* 11, no. 3 (August 03, 2014): 207-9, doi:10.1080/15427587.2014.936243.

⁴⁵ Richard Delgado, "The Imperial Scholar: Reflections on a Review of Civil Rights Literature," *University of Pennsylvania Law Review* 132, no. 3 (1984): 567, doi:10.2307/3311882.

⁴⁶ Alan Freeman, "Racism, Rights, and the Quest for Equality of Opportunity: A Critical Legal Essay," *Harvard Civil Rights-Civil Liberties Law Review* 23 (1988): 299.

that no activist should be turned away from an organization geared towards equality because of a superficial status if they have zeal for equality and progress.

While these criticisms are fair, they are easily handled. CRT's major problem is its exclusivity and how it accepts other groups or activists trying to actualize increased equality for individuals of marginalized races and lower socioeconomic classes. This concern would be eradicated with the union of the disciplines because CLS would shelter CRT's weakness with its greatest strength of inclusivity.

Reunification of the Critical Legal Disciplines

A major obstacle that the critical disciplines must face before joining together is answering, "Who is the Other?" CRT argues that it is the minority. Critical feminist theory argues that the Other is the woman. Queer theory regards disadvantaged groups based on sexuality as most deserving of devotion. However, CLS claims that they defend all people that belong to a disadvantaged socioeconomic class. CLS determines critical protection based on an analysis of power, not just exterior characteristics. In this, CLS attempts to answer Foucault's question, "How can the growth of capabilities be disconnected from the intensification of power relations?"⁴⁷ Critics respond by opening its membership to all mistreated groups that lack power.

Outside of CLS, the critical disciplines struggle theoretically with seeing an individual holistically, or as Crenshaw states, an intersectionality of multiple identities.⁴⁸ While all critical studies see people as a part of a whole, CLS is broad enough to view a gay, black woman as a gay, black woman instead of gay, female, or black. CRT is ready for this move. Two of their most prolific writers, Richard Delgado and Jean Stefancic argue, "No person has a single, easily stated, unitary identity."⁴⁹ However, CLS is the only critical branch that is equipped, at least suppositionally, to assist her as an individual. The disciplines could benefit from adopting CLS's broad method of analyzing power simpliciter instead of through a limiting nexus.

Before the disciplines can unify, CLS's dismissal of individual rights must be rectified. According to its critics, CLS's notion of rights is diametrically opposed to the rest of the critical legal fields. Whereas

⁴⁷"What Is Enlightenment," in *The Foucault Reader: An Introduction to Foucault's Thought*, ed. Paul Rabinow, by Michel Foucault (London: Penguin Books, 1984).

⁴⁸ Kimberlé Crenshaw, "Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics," *University of Chicago Legal Forum*, 8th ser., 1989, no. 1 (1989): Article 8.

⁴⁹ Delgado & Stefancic, *Critical Race Theory*, 9.

the majority of CRT views the acquisition of rights during the civil rights era as the greatest triumph of minority leadership, CLS believes that rights are merely a buzzword used by jurists to obfuscate their engagement in policy analysis.

An accurate understanding of CLS's view on rights supplies the necessary answer. Critics never contended that claimed "rights" that were won by minority activists were insignificant, only that, realistically, rights do not have an elevated status over ordinary law. A Foucauldian analysis shows that civil rights leaders took power. The narrative that the dominant American culture granted rights to minorities pacifies the power acquired, leaving it in the hands of the grantors. Interestingly, several critical race theorists agree with this analysis.⁵⁰ In the sense that power had to be taken, it implies that power can be lost. CLS's original concept does not diminish the civil rights movement's accomplishment. Rather, it improves upon it by acknowledging their sacrifice and gain but still promotes an ever-engaged struggle to maintain and seize more power. This active belief restrains groups from resting on their laurels. Gaining voting rights was substantial, but if not followed with more action, it becomes a dulling opiate that strips their power. A fundamental tenant of critical theory is that power can be lost, but CLS's agnosticism toward the religion of rights prevent people from holding to a belief in an all-encompassing power that simply does not exist.

A Proposal

Critical legal education in law schools across America is waning. According to Adrien K. Wing, a professor of law at the University of Iowa, clinical education is increasing, but funds are not. Teaching loads may increase, which would result in a severe blow to legal scholarship. Ultimately, Wing asks whether law schools will begin to train their students to meet the minimum requirements and pass the bar.⁵¹ Furthermore, many law schools do not have a course dedicated to a critical discipline.⁵² If the critical disciplines are to remain a force, they must push against the booming voices claiming that society has reached perfection because it is now classless, devoid of racism, and free of patriarchal domination. To combat these pernicious voices, critical studies must amplify theirs by rejoining.

⁵⁰ Jeffrey J. Pyle, "Race, Equality and the Rule of Law: Critical Race Theory's Attack on the Promises of Liberalism," *Boston College Law Review*, 6th ser., 40, no. 3 (May 1, 1999): Article 6.

⁵¹ Adrien K. Wing, "Is There a Future for Critical Race Theory?" *Journal of Legal Education* 66, no. 1 (Autumn 2016): 44.

⁵² *Ibid.*, 54.

While Critics were adamant that CLS was meant only to serve as a critique, there is a solution to the problem of separate disciplines. Those that still adhere to CLS must learn from CRT's advancements in legal philosophy and action. They must come down from on high and become public intellectuals, meaning they must intervene in the conversation that alters American thought instead of the seclusion of legal academia. Learning CRT's methods of utilizing the base provides such an opportunity.

Likewise, CRT should adopt the inclusive aspect of CLS by studying individuals based on socioeconomic class. CRT would not be required to forsake the people of color they have always defended. Instead, they could use their honed abilities to champion for all that have been disenfranchised. The process of each discipline learning from the other will take some time, but it is worth it to combine CRT's techniques of rallying common people and CLS's commitment to fight for all underrepresented people.

It is as if the critical disciplines are on a gameshow in competition with one another. However, like all of the contestants in *Black Jeopardy*, the critical disciplines agree on the majority of the answers. Small differences exist between them, but like the contestants, the separation is small. Instead of seeing the minor differences between disciplines, the critical methods need to reunify, deemphasize their differences, and focus on how an alliance could benefit the people they fight for.

The Process of Sanctification: A Bourdieusian Approach to the Declension of Power in New England Puritan Clergy

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Abstract

This paper explains the declension, or decline, of Puritan clerical power following the Great Migration and the conflict that ensued until Massachusetts lost its charter in 1684. Historian Perry Miller argued that an overall declension in Puritan culture occurred during this period. However, that notion has been largely dispelled. There is a resurging field exploring declension in areas outside of Miller's scope of Puritan culture. This paper shows that colonial New England existed as a functional theocracy by using Pierre Bourdieu's theory of symbolic capital to explain the conflict between secular and clerical power. For most of this struggle, ministers used symbolic and religious misdirection and conversion before significant historical incidents exposed the hidden power. This paper explores civil and economic power struggles in colonial New England during the decades following the Great Migration

to establish that Puritan culture did not largely decline. Instead, it was the Puritan clergy's power that waned during the seventeenth century.

Most Puritan families kept a copy of the Geneva Bible in their home. Puritans read the Bible as families, as congregations, and as a government. The Puritans' literacy rate was higher than that of their contemporaries because they taught children to read in hopes of biblical familiarity. Puritans had separated from the Catholic Church, in part, because their God-given right to read the Bible was restricted. In short, the Bible was vital to the Puritans of New England. The Puritans pointed to many scriptures to justify their intertwined religious government. Surely, Exodus 19 was one of those examples.

In this chapter of the Old Testament, Moses, Aaron, and the newly freed Israelites wander through the "wilderness" searching for the promised land, an image often borrowed and rhetorically invoked by the leader of the first wave of Puritan immigrants, John Winthrop.¹ In Exodus, Moses travels to the top of Mount Sinai where Jehovah reminds him of Israel's covenant that, if kept, will cause Israel to prosper. Verse six recounts Jehovah telling Moses: "Ye shalbe unto me also a kingdome of Priests, and an holy nation."² Moses is commanded that no one outside of whom Jehovah commands is allowed to climb the mount. In the penultimate verse of the chapter, Aaron is commanded to ascend Mount Sinai with Moses.³ Thus, Israel's civil government had the power of God through covenant, and the Puritans would too.⁴ The symbolism of this chapter invokes God's blessing for the New England Puritans' functional theocracy.⁵

¹ Alan Heimert, "Puritanism, the Wilderness, and the Frontier," *The New England Quarterly* 26, no. 3 (1953) doi:10.2307/362849.

² *The Bible and Holy Scriptures contained in the Old and New Testament* (Geneva: Rouland Hall, 1560), Exod. 19:6.

³ Aaron, Moses' brother, stood in place for Moses on several occasions during the Israelites' deliverance from Egypt. The priesthood is directed through Aaron's line. Ex. 40:12-15, Num. 16:40, 2 Chr. 26:18. The priesthood, while religious in many aspects, played a more significant role in the civil administration of the theocratic state than the Levites. 1 Kgs. 8:4, Ezra 2:70, John 1:19.

⁴ Ex. 24:14, 18. This verse shows that Aaron was appointed a judge in Israel. While not completely divorced from religious duties, judges in Israel played a largely secular role. Ex. 23:2, 6.

⁵ I classify Massachusetts Bay as a functioning theocracy because it required religious adherence to be a freeman—a voting member. Perry Miller, *Orthodoxy in Massachusetts 1630-1650* (Gloucester, MA: Peter Smith, 1965). While clergy members were banned from holding office, they did hold power in terms such as advisory and oversight. Francis J. Bremer, *The Puritan Experiment: New England Society from Bradford to Edwards* (Han-

The Puritans infused religion into every aspect of their lives. This worked during the Great Migration and for years after. However, it was impossible for Puritan orthodoxy to maintain its control for long in the face of a changing society, economic fluctuations, and governmental upheaval. By employing a Bourdieusian analysis of New England economics and civil government, I would suggest that, while Puritan culture did not decline in the years following the Great Migration, New England's functional theocracy lost control of New England by the time England revoked the Massachusetts Bay charter in 1684.

Theoretical Framework

For the purpose of this paper, I will be analyzing the power structure between ministers, magistrates, and common individuals through an approach based on the theories and studies of Pierre Bourdieu. Bourdieu is particularly useful because his social theories are designed to "unveil domination and the least visible forms of domination, so often hidden by common sense."⁶ Bourdieusian theory is perfect to address the power structure in New England culture because the contest for dominion was generally unseen. Bourdieu's theory will be used and explained throughout the paper, but a brief framework is necessary.⁷

Bourdieu views power through a Marxist lens, but instead of focusing purely on material capital, he gives voice to unseen capital.⁸ While economic and cultural capital are widely understood, I focus on symbolic capital because it sheds light on the inherent hegemonic structure of New

over, NH: University Press of New England, 1995), 93. Most importantly, from a Bourdieusian perspective, New England Puritan clergy gained symbolic capital which "functions to mask the economic domination of the dominant class and socially illegitimate hierarchy by essentializing and naturalizing social position ... noneconomic fields ... legitimate class relations through misrecognition." Craig Calhoun and Moishe Postone, "Habitus, Field, and Capital: The Question of Historical Specificity," in *Bourdieu: Critical Perspectives*, ed. Edward LiPuma and Craig Calhoun (Chicago, IL: University of Chicago Press, 1993), 66. Bourdieu explains that symbolic capital works through the means of transubstantiative transfer of symbolic capital into other forms of capital such as economic, political, social, or most importantly, the meta-field of power. Pierre Bourdieu, "The Forms of Capital," trans. Richard Nice, in *Handbook of theory and research for the sociology of education*, by John G. Richardson (New York, NY: Greenwood Pr., 1986), 242.

⁶ Monique De St Martin, "Une inflexible domination?" ed. Pierre Encrevé, in *Travailler avec Bourdieu*, ed. Rose-Marie Lagrave (Paris: Flammarion, 2007), 326.

⁷ It is important to note that while there are some definitions offered in this paper, Bourdieu's "thinking tools" are meant as guidelines that are "intended to be flexible and adaptable" for the study at hand. Terry Rey, *Bourdieu on religion: imposing faith and legitimacy* (Routledge, 2014), 43.

⁸ These terms will be used interchangeably throughout this paper.

England's functional theocracy. Symbolic power is based on "assumptions in the constitution and maintenance of power relations."⁹ Symbolic capital requires legitimation through symbolic labor performed by those that it benefits, but the affected group must not recognize how the actor benefits.¹⁰ For example, a preacher only produces symbolic power in a society that agrees that religion is important for reasons besides material capital. Then he must misdirect the laity by obscuring his real intentions.¹¹ The preacher's interest must be seen as legitimate, i.e., doing God's will. This process legitimates the preacher, leading the laity to respond with deference and obedience, thus the clergy becomes a ruling class. The magistrates need the ministers because they consecrate magisterial decisions through their symbolic power. Thus, the functional theocracy forms when the religious field is so powerful that all decisions must be consecrated by the clergy.

Historiography

Perry Miller, one of the foremost intellectual Americanists, resurrected Puritan studies, which led to an outpouring of Puritan scholarship that continues. Throughout his career, Miller focused on Puritan apostasy. He studied Puritan jeremiads, which were essentially diatribes directed at a congregation while simultaneously granting extensive power to ministers. These sermons led Miller to conclude that a general "apostasy" occurred among the Puritans.¹² Margaret Sobczak, a critic of Puritan decline, sums up Miller's version of declension as "a waning of spiritual commitment to the survival of particular ideas and a particular social order."¹³ It is important to note that Miller's argument was mostly concerned with spiritual apostasy, rather than an overall cultural decline.

Miller's conclusion on declension was roundly criticized by numerous scholars, including Edmund Morgan, one of Miller's doctoral advisees.¹⁴ Morgan acknowledged that Miller set the framework for future

⁹ David Swartz, *Symbolic power, politics, and intellectuals: the political sociology of Pierre Bourdieu* (Chicago, IL: The University of Chicago Press, 2013), 43.

¹⁰ Ibid.

¹¹ Bourdieu contends that, generally, this process happens subconsciously.

¹² Perry Miller, "Errand Into The Wilderness," *The William and Mary Quarterly* 10, no. 1 (1953): 8, doi:10.2307/2936876.

¹³ Margaret Sobczak, "Hoopes's Symposium on Perry Miller," *American Quarterly* 34, no. 1 (1982): 45, doi:10.2307/2712789.

¹⁴ Edmund S. Morgan, "An Address to the Colonial Society of Massachusetts, on the Occasion of Its Centennial," *The New England Quarterly* 66, no. 3 (1993): 357, doi:10.2307/366001.

However, not all of Morgan's statements of Miller's work were negative. It should be noted that Morgan referred to Miller's work as "the most imaginative and the most exhaustive

Puritan studies, but he criticized Miller for depicting the Puritans as a one-dimensional people.¹⁵

Furthermore, in this paper, I explore the notion of capital held by Puritan clergy held in 17th century New England. Historians Ira V. Brown and David E. Smith proved that ministers gained extensive power through millennialism preaching.¹⁶ James West Davidson supplemented this conclusion by showing that Congregationalists firmly believed in ministerial prophecy. Furthermore, they believed that they could bring about Christ's Second Coming.¹⁷

During the 17th century, only ministers connected the Bible to the symbols that revealed New England's destiny. Sacvan Bercovitch, the preeminent scholar of Puritan typology, demonstrated that typological rights endowed ministers with a consecrated power over their congregation.¹⁸

Recently, scholars have focused on the dismantling process of Puritan hegemony in New England. Darren Staloff forcefully addresses the power struggle between competing groups in his work, *The Making of an American Thinking Class*.¹⁹ He concluded that as power was removed from the government, common New Englanders justified political radicalism through the Bible, which led to the implementation of democracy.

Although Miller's original argument has lost support, a new field of Puritan decline has emerged along secular lines. Mark Valeri's monograph, *Heavenly Merchandise*, argued that international trade, although initially controlled by functional theocracy, eventually altered Puritan

piece of intellectual history that America has produced." In Edmund S. Morgan, "The Historians of Early New England," in *The reinterpretation of early American history; essays in honor of John Edwin Pomfrey*, by Ray Allen Billington and John E. Pomfret (San Marino, CA: Huntington Library, 1969), 52.

¹⁵ Morgan, *Historians of Early New England*, 53. Also, see Michael McGiffert, "American Puritan Studies in the 1960s," *The William and Mary Quarterly* 27, no. 1 (1970): 52, doi:10.2307/1923838.

¹⁶ Ira V. Brown, "Watchers for the Second Coming: The Millenarian Tradition in America," *The Mississippi Valley Historical Review* 39, no. 3 (1952): 445, doi:10.2307/1895004; David E. Smith, "Millenarian Scholarship in America," *American Quarterly* 17, no. 3 (1965): 535-549, doi:10.2307/2710907.

¹⁷ James West Davidson, *The logic of millennial thought: eighteenth century New England* (New Haven, CT: Yale University Press, 1977), 75.

¹⁸ Sacvan Bercovitch, *The Puritan Origins of the American Self* (New Haven, CT: Yale University Press, 2011); Sacvan Bercovitch, *The American Puritan Imagination* (London: Cambridge University Press, 1974). Sacvan Bercovitch, ed., *Typology and Early American Literature* (Amherst, MA: University of Massachusetts Press, 1972).

¹⁹ Darren Staloff, *The making of an American thinking class: intellectuals and intelligentsia in Puritan Massachusetts* (New York, NY: Oxford University Press, 2001).

morality.²⁰ I seek to situate my exploration of power relations along theocratic lines. I seek not to just note the changing circumstances in New England, but also to define the periods that provided critical mass for significant alterations in New England politics and culture.

Additionally, this paper builds upon Davidson's, Bercovitch's, and many other historians' arguments that demonstrated the power imbalance in colonial New England. I begin with examples of early religious control of civil government that slowly eroded as the clergy lost its control over orthodox standards. As with my economic argument, I identify critical junctures in New England history where the functional theocracy began unraveling.

Civil Government

The civil and ecclesiastical fields were the most heavily intertwined fields in colonial New England. The magistrates, as Puritan churchman Thomas Cartwright stated, were intended to be "nursing fathers" and protectors of the church.²¹ This relationship was stable for several years. While the ministerial class maintained control, civil officers were comfortable with their allotted power. However, the two fields could not co-exist indefinitely as long as they both sought to control the preeminent field of power.

The Massachusetts Bay Company was the initial investment of wealthy merchants seeking to replicate a profit-maximizing colony similar to Virginia. Religious thinkers, like John Winthrop and Richard Saltonstall, arrested control of the Company hoping to create a religious haven for Puritans where civil and religious power worked in concert as it did in ancient Israel. Winthrop, first governor of the Massachusetts Bay Colony, in a letter to his wife, prophesied that they would avoid a great calamity that would soon befall the wicked that remained in England:

It is a great favour, that we may enioye so much comfort and peace in these so euill and declininge tymes and when the increasinge of our sinnes giues vs so great cause to looke for some heauye Scquorge and Judgmt to be comminge vpon us: the Lorde hath admonished, threatened, corrected, and astonished

²⁰ Valeri, *Heavenly merchandize: how religion shaped commerce in Puritan America* (Princeton, NJ: Princeton University Press, 2010).

²¹ Thomas Cartwright and B. Brook, *Memoir of the life and writings of Thomas Cartwright, including the principal ecclesiastical movements in the reign of Queen Elizabeth* (London: J. Snow, 1845), 185.

vs, yet we growe worse and worse, so as his spirit will not all-
wayes striue with vs, he must needs giue waye to his furye at
last: he hath smitten all the other Churches before our eyes, and
hath made them to drinke of the bitter cuppe of tribulation, euen
vnto death...²²

Winthrop's utopian thinking was common among Puritans. They often invoked their own flight into the wilderness of Massachusetts as analogous to the flight to the Israelites to the Promised Land.²³ These comparisons motivated founding Company members to recruit like-minded people for their venture. As a result, the future Massachusetts Bay government would be homogenous.

The New England Puritans' repeated use of the civil covenant shows that church and state were hardly distinct. Aboard the ship that brought the first wave of immigrants to the Massachusetts Bay Colony, the *Arbella*, Winthrop delivered his renowned speech: "A Modell of Christian Charity," where he emphasized the Puritans' covenants with the Lord. He referred to the legal and religious meanings of covenant simultaneously. A portion of Winthrop's speech lays out the responsibility that each group member had for each other, known as the civil covenant, "Wee must ... make other's conditions our oune; reioice together, mourne together, labour and suffer together, allwayes haueing before our eyes our commission and community in the worke, as members of the same body."²⁴ Despite the strong references to civil government, all covenants bound individuals to God, not just to each other. The powerful covenant arrangement shows that religion was the essence of New England's civil government.²⁵

Individual participation in the civil covenant acted as a precursor to the establishment of towns, the regulation of voting members, and just

²² John Winthrop, "John Winthrop to Margaret Winthrop," John Winthrop to Margaret Winthrop, May 15, 1629. Accessed February 11, 2018, at <http://www.masshist.org/publications/winthrop/index.php/view/PWF02d052>.

²³ Naoki Onishi, "Puritan Historians and Historiography," in *The Oxford Handbook of Early American Literature*, ed. Kevin J. Hayes (Oxford: Oxford University Press, 2012), 95.

²⁴ John Winthrop, "John Winthrop: A Modell of Christian Charity, 1630," *John Winthrop: A Modell of Christian Charity*, 1630, August 1996. Accessed February 14, 2018, at <https://history.hanover.edu/texts/winthmod.html>.

²⁵ See generally, Charles E. Hambrick-Stowe, *The Practice of Piety Puritan Devotional Disciplines in Seventeenth-Century New England* (Chapel Hill: The University of North Carolina Press, 2014). Also, David D. Hall, *Worlds of Wonder, Days of Judgement: Popular Religious Belief in Early New England* (Cambridge, MA: Harvard University Press, 1990).

being a member of the community.²⁶ Philip Gorski, a sociologist of religion, summarizes the covenant experience: “the Puritans did not envision their polities as mere aggregations of individuals pursuing their private welfare, but as sacred corporations dedicated to higher principles.”²⁷ It is upon the backdrop of the covenant that we can comprehend just how much power the clergy held in colonial New England government.

Unlike a traditional theocracy, secular and clerical leaders were distinct. The clergy could not hold public office. However, the religious covenant continually intersected the civil covenant. Every formal civil covenant called upon the name of God. This notion of a binding between God and a community of individuals can be found in the Salem Covenant of 1629, which reads, “We Covenant with the Lord and one with another; and do bind our selves in the presence of God, to walk together in all his waies, according as he is pleased to reveale himselfe unto us in his Blessed word of truth.”²⁸ Officials consulted ministers when creating and enforcing law. With a few notable exception, like John Cotton, ministers were paid from community taxes.²⁹ Clergy members, under instruction from the magistrates, delivered Election Day sermons. During these sermons, preachers often advocated for specific governmental changes and officials.³⁰ These instances of mixing between church and state show that, while there was some delineation, there is enough evidence to conclude that the clergy held a substantial amount of power in the field of civil governance during the Great Migration. In the upcoming decades, the magistracy challenged the clergy, causing disruption within the functional theocracy.

Despite the functional theocracy’s rigid control, it would be challenged throughout its reign. Accounts of the banishments of Roger Williams and Anne Hutchinson have received excellent treatment from

²⁶ David A. Weir, “Early New England: A Covenanted Society,” in *Emory University Studies in Law and Religion* (Grand Rapids, MI: W. B. Eerdmans, 2004), 154.

²⁷ Philip S. Gorski, *American covenant: a history of civil religion from the Puritans to the present* (Princeton, NJ: Princeton University Press, 2017), 44.

²⁸ Jeffrey Barz-Snell, “The Long History,” *A ‘Short’ History of the First Church in Salem*. Accessed February 11, 2018, at <http://www.firstchurchinsalem.org/the-long-history/>.

²⁹ John Cotton argues that payment should be given “not of constraint but freely, brought by the givers as an offering to the Lord & laid down.” See John Cotton, *The true constitution of a particular visible church, proved by Scripture. Wherein is briefly demonstrated by questions and answers what officers, worship, and government Christ hath ordained in his chvrch* (London: Printed for Samuel Satterthwaite, at the Signe of the Black Bull in Budge Rowe, 1642).

³⁰ Michael Besso, “Thomas Hooker and His May 1638 Sermon,” *Early American Studies: An Interdisciplinary Journal* 10, no. 1 (2012): 206-7, doi:10.1353/eam.2012.0002.

numerous sources. Williams's separation doctrine and Hutchinson's antinomianism both challenged the religious-secular alliance. However, the appearance of the Quakers in colonial New England reveals a darker side to the alliance than previously witnessed in New England. Quakers were more determined civil ingrates than earlier dissidents. They relentlessly pushed Puritan leaders to the position where they were forced to determine whether religious toleration was an option or not. However, for the theocracy, tolerance was unallowable. During the latter half of the 17th century, Massachusetts Bay diversified. They saw their religious and civil covenants as the opposing side to the same coin. Without the civil covenant, leaders reasoned, separate covenants that protected English orderliness and godliness would disintegrate.

Quaker beliefs focused on an inner light that God gave liberally to all people. Quaker doctrine undermined the authority of ministers, the Bible, and the entire covenant system. In 1657, Quakers continued to disregard Puritan authority. The clergy could not stand by and watch Quakers dissuade their followers. Their covenants would not allow it, so they punished the heretical Quakers. Punishments were mild at first, but they quickly progressed to floggings, banishments, and, eventually, execution.³¹

Quakers were undeterred. They stoically bore their punishment. One specific account told of the Quaker—and former Puritan—Mary Dyer's execution. Her last words were of forgiveness: "for those that do it in the simplicity of their hearts, I desire the Lord to forgive them."³² Still more Quakers were killed during the crisis, but the brutal punishment did not have the intended effect. One of Dyer's prosecutors spoke for the entire ruling class when he expressed the failing sentiment, "Mary Dyer did hang as a flag for others to take example by."³³ Among many sympathetic outcries, a dismayed utterance came in response to Herodias Long's whipping, "Surely if she had not the spirit of the Lord she could not do this thing."³⁴

³¹ Patricia U. Bonomi, *Under the Cope of Heaven: Religion, Society, and Politics in Colonial America* (New York, NY: ACLS History E-Book Project, 2005), 27-29.

³² William Sewel, *The history of the rise, increase and progress of the Christian people called Quakers* (Philadelphia, PA: Friends Book Store, 1856), 291.

³³ Horatio Rogers, *Mary Dyer of Rhode Island, the Quaker martyr that was hanged on Boston* (Providence, RI: Preston & Rounds, 1896), 67.

³⁴ Humphrey Norton et al., *New-Englands ensigne: it being the account of cruelty, the professors pride, and the articles of faith: signified in characters written in blood, wickedly begun, barbarously continued, and inhumanly finished ... by the present power of darkness possess in the priests and rulers in New-England, with the Dutch also inhabiting the same land ... This being an account of the sufferings sustained by us in New-England ... 1657, 1658. With a letter to John Indicot, and John Norton, governor, and chief priest of Boston,*

Eventually, England demanded answers. New England responded by appealing to British secular law despite its rare use in the New England colonies. England was eventually mollified, but significant damage to the functional theocracy was done. Quaker numbers expanded. Many of their neophytes defied compulsive church attendance laws. Patricia Bonomi concludes, "Thus the Quaker incidents denote a crisis and a turning point in New England's attitude toward religious toleration."³⁵

The Quaker–Puritan conflict was the quintessential challenge to orthodoxy from the heretical. Bourdieu's theory on the struggle for power within the religious field is tailored for the study of the Quaker–Puritan conflict. The Puritans represented the orthodox hierarchy, while Quakers were the subversive heterodox. Bourdieu contends, "religion has social functions in so far as the laity expects justification of their existence as occupants of a particular position in the social structure."³⁶ Puritan ideology emphasized that colonists had been led into the "wilderness," just as Moses and the Children of Israel. If these settlers lost faith, they might leave the church. While this is upsetting to a congregation, departure would be damning for a functioning theocracy because of the likelihood of civil rebellion.

Quakers came as humble zealots, but they challenged the elite ruling ministers and magistrates of New England. Bourdieu explains that dominant culture, or religion, replicates itself—the method of maintaining power. The Puritan elite had replicated power for thirty years based on laity misrecognition. The laity mistakenly believed that the ruling class was superior because they controlled access to most forms of capital. With the arrival of the Society of Friends' gospel, the monopoly on the field of power was broken up. If this doctrine was accepted by the laity, Puritan hegemony would fall.

Still, the Quakers did not ring the death knell to Puritanism. However, New England's religious field had changed because the power within the Puritan religious field was fundamentally altered. Future Puritans were raised more tolerant towards religion because Quakers challenged Puritan orthodoxy. As a modern observer of tolerance, Ta-Nehisi Coates argues, tolerance does not appear immediately, rather it is a "bet

and another to the town of Boston. Also, the several late conditions of a friend upon Road-Iland (London: Printed by T.L. for G. Calvert, 1659), February 1659.

³⁵ Bonomi, *Under the Cope of Heaven*, 29.

³⁶ Pierre Bourdieu, "Legitimation and Structured Interests in Weber's Sociology of Religion," in *Max Weber, rationality and modernity*, by Sam Whimster and Scott Lash (London: Routledge, 2009), 124.

on the future.”³⁷ Ordinary religious protestors and thinkers continued to bet on a more tolerant future.

However, the most significant blow to the Puritan functional theocracy was the period surrounding the removal of Massachusetts Bay’s charter. During this period, New England Puritans definitively lost the power capital that enabled their control. Moving into the First Great Awakening, the church no longer directly governed as it had during the Great Migration. Puritan churches became much less hierarchical and authoritative than the Puritanism of 17th century New England.

In an effort to maintain control of the religious field, ministers, over several years, preached a series of jeremiads—sermons focused on the degenerate nature of Puritan society because of the apostasy among the second and third generations. The clergy had lost its monopoly as the gatekeeper to material capital because of the Quaker menace, so they took an alternate approach to maintaining control. Social historian Robert Pope provided ample evidence that a religious decline during the latter half of the 17th century did not take place, as the “need” for jeremiads suggested. Rather, it was the clergy that unnecessarily instigated a hysterical fear of religious declension to persuade younger generations of the need for their correction.³⁸

Preachers, including John Norton, typified God to a physician when he claimed, “God proposeth to us Remedy or Calamity; we have our option ...accept it...or look at sorrow.”³⁹ Thomas Walley analogized apostasy to illness, but he excused the ancient Hebrews for their sickness as prophetic guidance.⁴⁰ Walley’s obvious implication was that Puritans retained their prophetic council, in the form of ministers, and therefore had no excuse for their declension. Walley continued to focus on the power of orthodox preaching by any other doctrine as “occult and hid.”⁴¹

According to the minister Samuel Torrey, the only healing balm available for the younger generations was to become submissive and

³⁷ Ta-Nehisi Coates, “The Importance Of Being Politically Correct,” *The Atlantic*, May 29, 2009. Accessed February 14, 2018, at <https://www.theatlantic.com/entertainment/archive/2009/05/the-importance-of-being-politically-correct/18471/>.

³⁸ Robert G. Pope, *The half-way covenant: church membership in Puritan New England* (Princeton, NJ: Princeton University Press, 1969).

³⁹ John Norton, *Three choice and profitable sermons* (Cambridge, MA: Usher, 1664), 7.

⁴⁰ Thomas Walley, *Balm in Gilead to heal Sions wounds: or, A treatise wherein there is a clear discovery of the most prevailing sicknesses of New-England, both in the civill and ecclesiasticall state; as also sutable remedies for the cure of them: collected out of that spirituall directory, the Word of God.: Delivered in a sermon preached before the Generall Court of the colony of New-Plimouth on the first day of June 1669. Being the day of election there.* (Cambridge, MA: Printed by S.G. and M.J., 1670), 3.

⁴¹ *Ibid.*, 6.

humble.⁴² After the metaphor sickness and apostasy ran its course, Puritan preachers turned to the familial narrative of a disappointed father. In an often replicated sermon, William Stoughton predicated God's bestowal of His inheritance on the pious behavior of his children. He castigated his congregation by pronouncing that "a Parent expects more from a Child than from any other because of the Relation."⁴³ One of the famed New England Mathers, Eleazar, delivered a cutting line in his sermon, *A Serious Exhortation to the Present and Succeeding Generation*, when he ridiculed the second generation by asserting that their parents "will be so far from helping you that they will rejoice and bless God for executing Justice upon you to all Eternity; neither your fathers nor the God of your fathers will own you."⁴⁴ Despite condemning sermon after condemning sermon, religious hegemony was coming to an end in New England. Governmentally tolerated religion was gaining more traction in the Old World, and soon it would be imposed on its colonists.

Quakers and religious leaders were not alone in upsetting the New England Way. In 1669, John Locke wrote portions of *The Fundamental Constitutions of Carolina*. In Article 97, Locke argued, "there will unavoidably be of different opinions concerning matters of religion ... and it will not be reasonable for us, on this account, to keep them out, that civil peace may be maintained amidst diversity of opinions, and our agreement and compact with all men may be duly and faithfully observed."⁴⁵ Locke's language mandated tolerance, but his argument was more nuanced. He contradicted the Puritans' sacramental belief that a civil covenant only worked when it accompanied a religious covenant. Rather, Locke claimed that the only way a civil covenant could function

⁴² Samuel Torrey and Increase Mather, *An exhortation unto reformation: amplified, by a discourse concerning the parts and progress of that work, according to the word of God, delivered in a sermon preached in the audience of the General Assembly of the Massachusetts colony, at Boston in New-England, May 27, 1674, being the day of election there* (Cambridge, MA: Printed by Marmaduke Johnson, 1977), 37. Accessed February 18, 2018, at <http://name.umd.umich.edu/N00141.0001.001>.

⁴³ William Stoughton, *New-Englands true interest; not to lie: or, A treatise declaring from the word of truth the terms on which we stand, and the tenure by which we hold our hitherto-continued precious and pleasant things.: Shewing what the blessed God expecteth from his people, and what they may rationally look for from him.: Delivered in a sermon preached in Boston in New-England, April 29. 1668. Being the day of election there.* (Cambridge, MA: Printed by S.G. and M.J., 1670), 8.

⁴⁴ Eleazar Mather, *A serious exhortation to the present and succeeding generation in New-England* (Cambridge, MA: Drucker: Green and M. Johnson, 1671), 31.

⁴⁵ Francis Newton Thorpe, *The federal and state constitutions, colonial charters, and other organic laws of the states, territories, and colonies now or heretofore forming the United States of America. Vol. II. Florida-Kansas* (Washington, D.C.: G.P.O., 1909), *The Fundamental Constitutions of Carolina*, Article 97.

is by removing the religious requirement because religious views would always be unavoidably different.

Massachusetts Bay's functional theocracy was ultimately torn apart in 1684 with the annulment of the Massachusetts charter.⁴⁶ In October 1684, Massachusetts Bay lost its authority for self-governance when Britain removed its charter. Instead of Massachusetts' *Sola Scriptura*, it was reincorporated into an administrative system to be governed by England known as the Dominion of New England. Edmund Andros was installed as the royal governor. He quickly enraged colonists by suppressing civil liberties, but the ultimate transgression came when he used Boston's sacred Old South Church for Anglican services.⁴⁷

Colonists resisted by appealing to the civic-minded notion of being taxed without representation. The decades of the functional theocracy's disintegration came to a head as a strong separation developed between clergy and civil officials over the method of opposing Britain and Governor Andros. Merchants and civil officials opposed Andros, but ministers remained aloof, preferring to urge covenant renewal.⁴⁸ The clergy sought to regain the symbolic power that they had slowly lost. Instead of outright resistance, Ministers attempted to walk a middle ground by subtly misguiding the laity through outward concern for their spirituality. Harry Stout explains, "Sermons ... show how carefully ministers avoided pulpit commentary on explosive political issues..."⁴⁹ With William of Orange's ascension to the throne in England during the Glorious Revolution, New England hoped for a reestablished charter and return to old ways. They felt so empowered that the British colonists overthrew Andros.

However, William of Orange, who became William II of England, did not prove to be a saving grace for the clergy. The new King instituted stronger policies of religious tolerance. This combined with the revocation of the charter in 1684 led to the end of the clergy's power over civil affairs came.

⁴⁶ A charter similar to the first was restored in 1691, but there were significant changes from the original. Religious qualifications to vote were exchanged for property requirements, the English monarch appointed senior governmental officials rather than their being elected, and King William made efforts to ensure that New England would not return to religious rule. David S. Lovejoy, *The Glorious Revolution in America* (Wesleyan University Press, 1987).

⁴⁷ William Henry Whitmore, *The Andros tracts* (Boston, MA: Printed for the Society by T.R. Marvin & Son, 1868), 26, October 17, 2011. Accessed February 19, 2018, at <http://www.gutenberg.org/files/37773/37773-h/37773-h.htm>.

⁴⁸ Harry S. Stout, *The New England soul: preaching and religious culture in colonial New England* (Oxford: Oxford University Press, 2012), 116.

⁴⁹ *Ibid.*, 117.

Philosophers, such as John Locke, articulated William III's notion for religious tolerance. Locke reasons:

I esteem it above all things necessary to distinguish exactly the business of civil government from that of religion... If this be not done, there can be no end put to the controversies that will be always arising between those that have, or at least pretend to have ... a concernment for the interest of men's souls..."⁵⁰

Locke highlights the Bourdieusian theory that individuals use their status to procure symbolic power. People are in danger when a civil government does not tolerate religion because, in Locke's words, "God has [n]ever given any such authority to one man over another, as to compel anyone to his religion. Nor can any such power be vested in the magistrate..."⁵¹ He seemingly attacks the Puritan functional theocracy because the civil covenant only functions when it is divorced from religion.⁵²

The clergy's symbolic capital had been eroding for decades. They would never regain their capital that they held during the time of the Great Migration. It became completely impossible following the changing way of thinking as expressed by Locke because symbolic power is produced when lay perception is misguided and misinterpreted as selfless acts. He conceptualized what the New England laity had been experiencing for years. With the removal of the charter and the advent of religious tolerance and years of ministerial intolerance, the clergy lost its capital in colonial New England.

Economy

Historians often describe merchants as the preeminent citizens of 18th century New England.⁵³ Things were not the same in the 17th century. Merchants were forced to bow to the clergy's doctrine. A specific example of clergy dominance can be shown through Robert Keayne. Keayne was a notable merchant during the Great Migration. He plied his trade with obeisance to the clergy's dogma. For a time, Keayne's story demonstrates how a strong Puritan religious field dominated New England but then slowly declined until religion had little input on trade. Robert

⁵⁰ John Locke, *Two Treatises of Government and a Letter Concerning Toleration*, ed. Ian Shapiro (New Haven, CT: Yale University Press, 2003), 218.

⁵¹ *Ibid.*

⁵² *Ibid.*, 219.

⁵³ Bernard Bailyn, *The New England merchants in the seventeenth century* (Cambridge, MA: Harvard University, 1955).

Keayne “was a good citizen, a man who obeyed the laws, carried out his social obligations, never injured others.”⁵⁴ The preceding sentence is the opening sentence of Edmund Morgan’s masterpiece, *The Puritan Family*. This description, although not meant directly for Keayne, could not describe a colonist better. Morgan continues, “This man, this paragon of social virtue, the Puritans said, was on his way to Hell, and their preachers continually reminded him of it.”⁵⁵ This begs the question: Why remind people of this “civil man” going to Hell?

By all accounts, Keayne was a strict adherent to Calvinism, as practiced in Puritan New England. He attended sermons in London and New England, taking fastidious notes.⁵⁶ Keayne also recorded instances where he accompanied John Cotton on church discipline hearings of Ann Hibbens and Richard Waits.⁵⁷ During the antinomian scare, Keayne distanced himself from wealthy Boston merchants that gravitated toward the heresy, despite many of them being his commercial partners.⁵⁸ Despite his zeal, Keayne was not purely devoted to Puritanism. Prior to his conversion, he was a guild member to the Merchant Taylors’ Company.⁵⁹ As with many guilds, the Merchant Taylors remained fairly agnostic about religion.⁶⁰ Rather, the guild was directed by guiding principles. Indeed, Mark Valeri contends that Merchant Taylors was essentially a Christian church without the theology.⁶¹ While guilds engaged in many of the same projects as churches, guilds’ motives were entirely wrong. Instead of invoking God as the source of their charity, merchant guilds were humanists. Keayne saw no conflict between humanism and Puri-

⁵⁴ Edmund S. Morgan, *The Puritan family. Religion & domestic relations in seventeenth-century New England* (Harper & Row: New York, 1966), 1.

⁵⁵ *Ibid.*

⁵⁶ Robert Keayne, *Note-Book kept by Capt. Robert Keayne, an early settler of Boston*. (Cambridge, MA: J. Wilson & Son, 1889), 5.

⁵⁷ *Ibid.*, 4-7.

⁵⁸ Emery Battis, *Saints and Sectaries Anne Hutchinson and the Antinomian Controversy in the Massachusetts Bay Colony* (Chapel Hill, NC: University of North Carolina Press, 2012), 268, 273-75.

⁵⁹ Valeri, *Heavenly Merchandize*, 18.

⁶⁰ There were periods where the guild would throw allegiance to one religion or another based on increased economic opportunity. At one point, under Sir Thomas White, the Merchant Taylors built the College of St. John as an expression of Anglican piety, but even ties to the college were severed when later economic benefit arrived. See: "The College of St John the Baptist was founded in 1555 by Sir Thomas White, a wealthy London merchant tailor," St John's College. Accessed February 3, 2018, at <https://www.sjc.ox.ac.uk/discover/about-college/history/>.

⁶¹ Valeri, *Heavenly Merchandize*, 17.

tanism. There were some minor incongruences, like usury, but the Merchant Taylors fought against unsavory business practices as well.⁶² Still, Keayne, the “civil man,” threatened the clergy legitimacy. They derived their power from the community’s uniform belief that ministers were the group that granted access to prosperity in Massachusetts. Bourdieu tells us that the religious specialist must convince the laity that the clergy hold the majority of prestige, honor, biblical knowledge, and educational credentials.⁶³ Keayne was threatening to disrupt religious power with the doctrine of humanism that undercut the core tenants. As Keayne served for reasons besides God’s command, he gained prestige and honor, not the church and its officials. While humanism did little to enhance Keayne’s biblical knowledge, it did enhance his standing in the community as having a highly sophisticated knowledge that could contend with the Puritans’ widely accepted notion that the Bible was the only reliable source of divine revelation.

The magistrates, the visible power of the functional theocracy, brought Keayne to trial for price gouging. Keayne lost the trial and was fined an unseemly £200.⁶⁴ Despite the church being an active participant in the civil trial, nonetheless it still censured Keayne, a punishment just below full excommunication. Even after the draconian sentences, Keayne devised nearly a third of his worldly wealth toward civic and religious projects to improve a community that had rejected him.⁶⁵ Robert Keayne certainly was a civil man, and if the 17th century Puritans are correct, he, just like any other Puritan, could be in Hell.

Eventually, colonial New England would transition from an agrarian economy to a mercantile economy. Interestingly, it took a major depression that lasted throughout the 1640s for the church to tolerate

⁶² Charles M. Clode, *The early history of the Guild of Merchant Taylors of the fraternity of St. John the Baptist, London: with notices of the lives of some of its eminent members*, vol. II (London: Harrison, 1888), 278.

⁶³ David Swartz, "Bridging the Study of Culture and Religion: Pierre Bourdieu's Political Economy of Symbolic Power," *Sociology of Religion* 57, no. 1 (1996): 76, doi:10.2307/3712005. In regard to these conditions, it was imperative that the ministers maintained a working relationship with the magisterial class. To this end, the magistrates, at least early in New England history, often deferred to the elders' decisions, and they almost always consulted them on important decisions, lest the magistrates lose clerical support via the election sermon, etc.

⁶⁴ This would later be reduced to £80.

⁶⁵ Robert Keayne and Bernard Bailyn, *The apologia of Robert Keayne; the last will and testament of me, Robert Keayne, all of it written with my own hands and began by me, mo: 6:1:1653, commonly called August; the self-portrait of a Puritan merchant* (Gloucester, MA: Harper & Row, 1970), Accessed February 11, 2018, from <https://www.colonialsociety.org/node/654#rwl01>.

merchants. It was the New England merchants that dragged New England out of the bleak depression that nearly ruined its colonial mission. Massachusetts Bay developed in the 1630s because of immigration during the Great Migration. Each new wave built homes, boosted the agricultural market, and required imports. Beginning in 1640, migration to New England nearly ceased.⁶⁶ The circumstances that allowed New England's unusual economy to thrive concluded, and with it, a decade-long depression commenced.⁶⁷ Creditors refused to loan money because the General Court protected the debtor at the money lender's expense. Religious power continued to restrict financiers' and merchants' actions throughout the 1640s. Finally, when the colony was on the verge of ruin, the General Court reluctantly loosened its economic grip. The depression lifted once credit was established. As merchants began business, an immigrant-dependent economy was replaced by a robust Atlantic trade that would sustain Massachusetts for centuries.⁶⁸

Bourdieuian theory explains that the overlap of the religious and economic fields allowed merchants to challenge the clergy in this contest. Ministers had crossed into the sphere that traditionally belonged to financiers and merchants. In this way, the ecclesiastical field opened themselves up to be challenged not just in the economic field, but also in the religious field. Bourdieu's notion of symbolic power is pertinent for this conflict. Clergy members gained symbolic power or legitimacy because they were able to misrepresent their interest in economics. Instead of appearing to be concerned with the task of everyday business, clergy members misrepresented their interests as spiritual, thus "legitimizing the social order" they had created.⁶⁹ Ministers lost their control of the economic field, because as Bourdieu states, the "monopoly of cultural legitimacy and the right to withhold and confer this consecration in the name of fundamentally opposed principles: the personal authority called for by the creator and the institutional authority favoured by the teacher."⁷⁰ The decade-long depression severely questioned the orthodox

⁶⁶ England began a reformation process that rectified Puritans' past reasons for leaving England. The mother country removed the desire to seek fortune across the ocean by increasing religious tolerance.

⁶⁷ Marion H. Gottfried, "The First Depression in Massachusetts," *The New England Quarterly* 9, no. 4 (1936): 655-57, doi:10.2307/360989.

⁶⁸ *Ibid.*, 658-59. A specific industry that was crucial for New England discharging its depression was the advent of the shipbuilding industry. The industry not just procured profit for owners and laborers, but it provided a valuable export and ready access to ships for New England merchants.

⁶⁹ Swartz, *Bridging*, 77.

⁷⁰ Pierre Bourdieu, "Intellectual field and creative project," in *Knowledge and Control: New Directions for the Sociology of Education: Conference: Papers*, ed. M. F. D. Young (London: Collier-Macmillan, 1971), 178.

view that merchants were to be questioned and scrutinized for their business methods. Now, these despised merchants were the saviors of the colonies.⁷¹ The clergy retreated to form a dialectical doctrine known as providence. Interestingly, providence took on an economic approach to God's favor/disfavor similar to the invisible hand. Providence led one to believe that good or ill that befell people was an indicator of God's judgment on their activities. If you prospered, God was pleased, and if you did not, it was because God was unhappy with you. The clergy could no longer mandate appropriate business practices, as they had with Robert Keayne. Instead, God would be the judge.

Conclusion

Historians have argued over spiritual declension among New England Puritans for decades. Indeed, there was a decline, but not how Perry Miller described. The decline came in Puritan orthodoxy's power in New England's functional theocracy. In time, the Quaker issue, revocation of the Massachusetts Bay charter, and improved notions of religious tolerance led to significant change in the way clergy exercised their capital in colonial New England. They exhausted their symbolic capital during the fight to maintain its hegemonic status, and as a result they lost most of their civil power. Indeed, an observer during America's Revolutionary Period lamented that the clergy were "not as valuable an order of men now as they used to be."⁷²

Similarly, the Puritan clergy saw merchants encroaching upon their theocratic power. The magistrates had been the nursing fathers they were established to be for years, but merchants gave no indication of such support. During the Great Migration, and for years after, ministers prosecuted merchants on religious grounds. It worked until merchants dragged New England out of a severe depression, thus, dispelling the notion that the clergy was the source for all truth. Eventually, merchants challenged ministers for control. Clerical retreat is evidenced by the concept of God's providence replacing direct ministerial control.

⁷¹ In London, a steady stream of articles, plays, and tracts started to portray the merchant as a hero and having an "Inquisitive Genius", rather than the villain. Thomas Sprat, the Bishop of Rochester, reflects the diminished power of the clergy, when he stated, "But of the English Merchants I will affirm, that in all sorts of Politeness, and skill in the World, and humane affairs, they do not onely excel them, but are equal to any other sort of men amongst us." Thomas Sprat and Abraham Cowley, *History of the royal-society of London: for the improving of natural knowledge* (Ann Arbor, MI: Oxford University Press, 2003), 88, Accessed February 11, 2018, at <https://quod.lib.umich.edu/e/eebo/A61158.0001.001/1:7?rgn=div1;view=fulltext>

⁷² "Livingston Papers," Thomas Tillotson to Robert R. Livingston, January 7, 1779, in *Social Structure of Revolutionary America* (Princeton, NJ: Princeton University Press, 2015).

When the Puritan preachers delivered jeremiad after jeremiad, enumerating the ills that infested Puritan culture, they revealed symbols from the Old Testament. Preachers rarely examined the New Testament. Closer scrutiny of Christ's responses to the religious leaders of the Jews would have been enlightening. In Mark, Christ condemns the Jewish clergy that so closely mirrored Puritan ministers, "Esai [Isaiah] hath prophecied wel of you, hypocrites, as it is written, This people honoreth me with their lippes, but their heart is farre away from me. 7) But they worship me in vaine..."⁷³

The Puritan clergy was so engorged by their religious power that they were blind to their own shortcomings. They connected so many symbols and types for the laity that they did not "first cast out the beam out of [their] own eye" prior to removing "the mote of [their] brother's eye."⁷⁴ Because of the ministers' impaired vision, the functional theocracy lost its control of colonial New England, but New England culture flourished without the weight of guilt and shame imposed by a religiously controlled government.

⁷³ Mark 7:6-7.

⁷⁴ Matt. 7:5.

Demography and Information Technology Affect Religious Commitment among Latter-day Saints in Utah and the Intermountain West

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Abstract

Studies show that defections from organized religion are increasing in the United States. Consistent with this national trend, defections from The Church of Jesus Christ of Latter-day Saints (the LDS, or Mormon Church) are also increasing. In 1992, demographers estimated that 3–4% of people baptized into the LDS Church had defected from the faith. But by 2015, over a third of those baptized had defected. This paper uses data from various surveys of U.S. Mormons to identify specific reasons for the rise in defections from the faith. Findings show that this phenomenon is largely concentrated in Utah and adjacent states. Data suggest that changing demographics in Utah have diluted the state's religious subculture, making it easier for less-committed Mormons to

leave. I find limited support for the theory that encountering information critical of the church on the internet is a catalyst for defection.

Studies show that defection from organized religion is increasing in the United States.¹ People with no religion now outnumber Roman Catholics, the nation's largest denomination.² Consistent with this national trend, defection from The Church of Jesus Christ of Latter-day Saints (the LDS or Mormon Church) is also increasing. In 1992, demographers estimated that 3–4% of people baptized into the LDS Church had defected from the faith.³ But in 2015, the Pew Research Center found that 36 percent of people raised LDS had defected.⁴ Other recent studies have similar findings.⁵ Thus, while the LDS Church continues to grow through missionary outreach and high birth rates, there are disproportionately more former Mormons now than in previous decades.⁶

This paper uses a representative sample of Mormons in the United States to identify reasons for this change. I find limited evidence for the notion that information technology is a catalyst for defection—an explanation advanced by ex- and anti-Mormon activists (hereafter called “activists”) and journalists in Utah. I find more evidence that demographic change in Utah and the Intermountain West is eroding aspects of the Mormon subculture that have heretofore restrained less-committed church members from severing ties with the faith.

¹ Public Religion Research Institute, “Exodus: Why Americans are Leaving Religion—and Why They’re Unlikely to Come Back,” 2016. Accessed November 14, 2018, at <https://www.prri.org/wp-content/uploads/2016/09/PRRI-RNS-Unaffiliated-Report.pdf>. Joel Thiessen and Sarah Wilkins-Laflamme, “Becoming a Religious None: Irreligious Socialization and Disaffiliation,” *Journal for the Scientific Study of Religion* 56:1 (2017) 64–82.

² Pew Research Center, “America’s Changing Religious Landscape,” 2015, p. 3. Accessed November 14, 2018, at <http://www.pewforum.org/2015/05/12/americas-changing-religious-landscape/>. Public Religion Research Institute, “America’s Changing Religious Identity: Findings from the 2016 American Values Atlas,” 2017, p. 42. Accessed November 14, 2018, at <https://www.prri.org/wp-content/uploads/2017/09/PRRI-Religion-Report.pdf>.

³ Tim B. Heaton, “Vital Statistics,” in *Latter-day Saint Social Life: Social Research on the LDS Church and its Members*, ed. James T. Duke, pp. 111–114. Provo, UT: Religious Studies Center, Brigham Young University, 1998.

⁴ Pew, “America’s Changing Religious Landscape,” 39.

⁵ Rick Phillips and Ryan Cragun, “Contemporary Mormon Religiosity and the Legacy of ‘Gathering,’” *Nova Religio: The Journal of Alternative and Emergent Religions* 16:3 (2015): 77–94.

⁶ Rick Phillips, Ryan T. Cragun and Barry A. Kosmin, “Increasing Sex Ratio Imbalance among Utah Mormons: Sources and Implications,” *Interdisciplinary Journal of Research on Religion* 11 (2015): 1–27.

The Activist Explanation

Activists, journalists, and some LDS leaders contend that increasing defection from Mormonism is linked to the rise of the internet. Activists claim that media and sermons published by the church present a faith-promoting view of Mormon history. These media and sermons often avoid controversial episodes from the church's past or omit the interpretation of these episodes favored by secular scholars. According to activists, in previous decades this frank portrayal of Mormon history was not widely known among Latter-day Saints. The rise of the internet provided a worldwide platform to disseminate this portrayal. Activists claim that Latter-day Saints are now finding this information while searching the internet, and this causes some to lose their faith.⁷

The activist explanation has been promulgated by journalists.⁸ It has also been acknowledged in LDS Church magazines and by church leaders.⁹ For example, Elder Quentin Cook, a member of the Quorum of the Twelve Apostles, said:

Some have immersed themselves in internet materials that magnify, exaggerate, and, in some cases, invent shortcomings of early Church leaders. Then they draw incorrect conclusions that can affect testimony. Any who have made these choices can repent and be spiritually renewed.¹⁰

Some former Latter-day Saints describe their defection from Mormonism in terms consistent with the activist explanation.¹¹ The rise of

⁷ Edward Marshall Brooks, "Disenchanted Lives: Apostasy and Ex-Mormonism among the Latter-day Saints," PhD dissertation, Rutgers University, 2015. See also Benjamin Knoll, "Many Mormons Are Unaware of the Messy Details of LDS Church History," *Huffington Post*, 24 November 2014. Accessed November 14, 2018, at https://www.huffingtonpost.com/benjamin-knoll/many-mormons-are-unaware-_b_6195784.html.

⁸ Laurie Goodstein, "Some Mormons Search the Web and Find Doubt," *New York Times*, 20 July 2013. Peter Henderson and Kristina Cook, "Mormonism Besieged by the Modern Age," *Reuters*, 30 January 2012. See also: Kristina Smith, Lindsey Williams and Miranda Facer, "Openness Influences LDS Millennials," *The Daily Universe*, 23 February 2016.

⁹ Hugo Montoya, "Overcoming the Danger of Doubt," *Ensign*, June 2017, 47.

¹⁰ Quentin Cook, "Can Ye Feel So Now?" A sermon delivered in the October 2012 General Conference of the Church of Jesus Christ of Latter-day Saints. Online at: <https://www.lds.org/general-conference/2012/10/can-ye-feel-so-now?lang=eng>.

¹¹ Hundreds of accounts from individual ex-Mormons that conform to the activist narrative can be found online here: <http://www.exmormon.org/stories.htm>. See also Brooks, "Disenchanted Lives." Accessed November 14, 2018.

the internet is associated with religious disaffiliation among members of other denominations.¹² But is this the modal cause of defection?

The only evidence addressing this question comes from a survey of former or doubting Mormons conducted in 2011. In this survey, concerns about the unexpurgated history of the church was a factor in the doubts or defection of 70% of respondents.¹³ However, this survey was based on an availability sample and was distributed in online venues where disaffected Mormons congregate. Hence, these findings cannot be generalized to a larger population.

To date, there are no studies based on representative samples exploring why Mormons leave the church. In the following section, I assess the utility of the activist explanation by examining Mormon respondents to the General Social Survey (hereafter GSS). The GSS is a federally funded, nationally representative survey that has been collecting data on social trends for over 40 years.¹⁴ After assessing the activist explanation, I formulate an alternative explanation for rising defections within Mormonism.

Regional Patterns of Defection

Figure 1 presents GSS data on defection from Mormonism. The GSS does not ask specific questions about religious apostasy, but it does ask respondents for their current religious affiliation and for their religious affiliation at age 16. Those who were LDS at age 16 but had some other religion (or no religion) when surveyed are self-professed defectors.¹⁵ The graph compares the 21st century—the era of the internet—with previous waves of the survey. The black bars represent the percentage of people in Utah and the Intermountain West¹⁶ who said they were

¹² Paul K. McClure, “Tinkering with Technology and Religion in the Digital Age: The Effects of Internet Use on Religious Belief, Behavior, and Belonging,” *Journal for the Scientific Study of Religion* 56:3 (2017) 481-497.

¹³ “Understanding Mormon Disbelief.” Accessed November 14, 2018, at http://www.whymormonsquestion.org/wp-content/uploads/2012/05/Survey-Results_Understanding-Mormon-Disbelief-Mar20121.pdf.

¹⁴ Aside from the U.S. Census, the General Social Survey is the most utilized data set in the social sciences. The survey is administered to a representative sample of U.S. residents over the age of 18. The first wave of the GSS was administered in 1972. The most recent wave was administered in 2016. Details about the history and data collection methods of the General Social Survey is online at: <http://gss.norc.oregon.edu/About-The-GSS>.

¹⁵ This measure of defection may slightly underestimate the number of defectors, because those who left the church before age 16 are not counted.

¹⁶ According to the GSS, Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming comprise the Mountain region. The Mountain region contains less than 10% of the U.S. population but contains more than half of all U.S. Mormons. Within the Mountain region, Mormons are most densely concentrated in Utah and in counties that border

raised Mormon but who no longer consider themselves LDS. The gray bars show these same figures for Mormons in the rest of the nation.

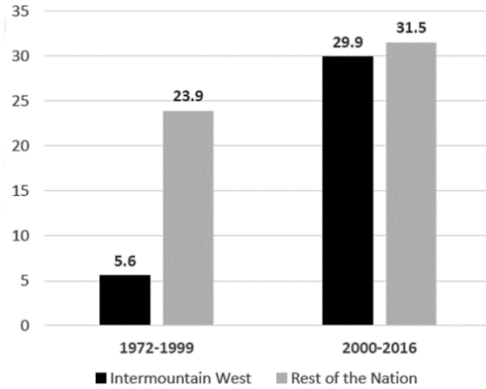


Figure 1: Percent of people claiming to be LDS at age 16 who are no longer LDS, by region (General Social Survey).

Throughout the last quarter of the 20th century, only 5.6% of survey respondents in Utah and the Intermountain West who were raised LDS were defectors. The rate for the rest of the nation was 23.9%. Thus, the church has traditionally been better at retaining members in places where it has a strong presence than in places where it is just one church among many.¹⁷ But since 2000, the rate of defection in Utah and the Intermountain West has more than quintupled and is now statistically indistinguishable from that in the rest of the nation. Outside Utah and the Intermountain West, defections increased from 23.9% to 31.5%, which seems consistent with the general, nationwide trend of rising religious disaffiliation.¹⁸

If the activist explanation is the best explanation for increasing defections from Mormonism, then how can we account for this regional disparity? Why is a dramatic increase in defections observed only in Utah and the Intermountain West? Since there is no reason to believe that Mormons in the Rocky Mountain states are more likely to have internet connections or spend more time online than Mormons elsewhere

Utah in other states. See Phillips and Cragun, "Legacy of 'Gathering,'" *Nova Religio*, 81-82.

¹⁷ Phillips and Cragun, "Legacy of the 'Gathering,'" 77-94.

¹⁸ Pew Research Center, "U.S. Public Becoming Less Religious," 2015. Accessed November 14, 2018, at <http://www.pewforum.org/2015/11/03/u-s-public-becoming-less-religious/>.

in the nation, it is necessary to augment the activist explanation with another explanation that is consistent with this regional pattern. In the next section, I argue that recent changes in the religious demography of Utah and parts of adjacent states supply such an explanation.

Mormon Subculture and Demography

Throughout the 20th century, Mormons were more concentrated in Utah than was any other denomination in any other state.¹⁹ LDS concentration in Utah peaked in 1990 at 77%.²⁰ However, excepting states adjacent to Utah, Mormons are sparsely distributed. No state east of the Mississippi River is more than 1% LDS.²¹ In 1990, Kosmin and Lachman observed: “Mormons are the most geographically isolated and uniquely distributed religious group in the nation.”²² Thus, Mormons have dominated their Rocky Mountain stronghold but are a small minority elsewhere.

Studies show the concentration of Mormons in Utah and parts of adjacent states has traditionally produced higher levels of religious activity than in places where Mormons are sparse.²³ For example, studies from the 1960s through the 1990s found that Mormons in Utah and the Intermountain West attended church more frequently than other Mormons.²⁴ This holds for other measures of religious activity as well.²⁵

The concentration of Mormons in Utah fosters a unique religious subculture that emanates from the rituals and doctrines of the LDS

¹⁹ Rick Phillips and Ryan Cragun, “Mormons in the United States 1990-2008: Socio-demographic Trends and Regional Differences,” Trinity College, 2011. Accessed November 14, 2018, at <http://commons.trincoll.edu/aris/files/2011/12/Mormons2008.pdf>.

²⁰ Rick Phillips, “Saints in Zion, Saints in Babylon: Religious Pluralism and the Transformation of Mormon Culture,” PhD dissertation, Rutgers University, 2001, p. 8. See also: *Deseret News 1991-1992 Church Almanac*, Salt Lake City: Deseret News, 1991, p. 94, 109.

²¹ Phillips and Cragun, “Mormons in the United States 1990-2008,” 2.

²² Barry A. Kosmin and Seymour P. Lachman, *One Nation Under God: Religion in Contemporary American Society*, New York: Harmony Books, 1993, p. 61.

²³ Rodney Stark and Roger Finke, “Religions in Context: The Response of Non-Mormon Faiths in Utah,” *Review of Religious Research* 45:3 (2004) 293-298.

²⁴ Armand L. Mauss, *The Angel and the Beehive: The Mormon Struggle with Assimilation*, Urbana, IL: University of Illinois Press, 1994, pp. 41-42. Stan Albrecht, “The Consequential Dimension of Mormon Religiosity” in *Latter-day Saint Social Life: Social Research on the LDS Church and its Members*, ed. James T. Duke, pp. 253-292-114. Provo, UT: Religious Studies Center, Brigham Young University, 1998.

²⁵ Rick Phillips, “Religious Market Share and Mormon Church Activity,” *Sociology of Religion* 59:2 (1998) 117-130.

Church but cannot be wholly reduced to them.²⁶ This *sui generis* subculture promotes Mormon religious activity in ways that cannot be replicated elsewhere.²⁷ The important elements of this subculture have been described by social scientists.²⁸ These include a religious milieu with commonly held beliefs and the conflation of church and civic norms. I consider the impact of these elements below.

Commonly Held Beliefs

Studies show that people tend to believe what others around them believe. Religious beliefs that are widely shared in society have an aura of plausibility because they seem axiomatic and authoritative.²⁹ (For example, many Americans who have never read the Bible and know very little about it are nevertheless convinced it is inerrant.³⁰) Because religious beliefs are not generally supported by empirical evidence and cannot be logically deduced, they must be sustained through social interaction. Hence, interaction with coreligionists bolsters the believability of religious claims. Conversely, competing religious claims can cancel each other out.³¹ According to Joseph Smith—the founding prophet of Mormonism—a desire for theological unity and aversion to religious

²⁶ D. W. Meinig, “The Mormon Culture Region: Strategies and Patterns in the Geography of the American West, 1847-1964,” *Annals of the Association of American Geographers* 55 (1965) 191-220. Dean L. May, *Utah: A People's History*, Salt Lake City: University of Utah Press, 1987. Jessie L. Embry, *Mormon Wards as Community*, Binghamton, NY: Global Publications, Binghamton University, 2001. Jedediah Smart Rogers, “The Latter-day Influence in 2050 Utah,” in *Utah in 2050: Glimpses of Our Future*, ed. Michael K. Winder, pp. 81-93. Salt Lake City: Eborn Books, 2003. Michael B. Toney, Chalon Keller and Lori M. Hunter, “Regional Cultures, Persistence and Change: A Case Study of the Mormon Culture Region,” *The Social Science Journal* 40:3 (2003) 431-445.

²⁷ Lawrence A. Young, “The Religious Landscape,” in *Utah in the 1990s: A Demographic Perspective*, ed. Tim B. Heaton, Thomas A. Hirschl, and Bruce A. Chadwick, 155-166. Salt Lake City, UT: Signature Books, 1996. Howard M. Bahr, and Renata Tonks Fortse. 1998. “Toward a Social Science of Contemporary Mormonism,” in *Latter-day Saint Social Life: Social Research on the LDS Church and Its Members*, ed. James T. Duke, pp. 133-201. Provo, UT: Brigham Young University Religious Studies Center, 1998.

²⁸ Todd L. Goodsell, “Reconsidering Solidarity in the Mormon Village.” M.S. Thesis, Brigham Young University, 1998. Brent L. Top and Bruce A. Chadwick, *Rearing Righteous Youth of Zion: Great News, Good News, Not-So-Good News*. Salt Lake City, UT: Bookcraft, 1998. John B. Wright, *Rocky Mountain Divide: Selling and Saving the West*. Austin, TX: University of Texas Press, 1993. Phillips, “Saints in Zion, Saints in Babylon.”

²⁹ Peter L. Berger, *The Sacred Canopy*, New York: Anchor Books, 1967. Peter L. Berger and Thomas Luckman. *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*, New York: Anchor, 1966.

³⁰ Pew Research Center, “U.S. Religious Knowledge Survey,” 2010. Accessed November 14, 2018, at <http://www.pewforum.org/2010/09/28/u-s-religious-knowledge-survey/>.

³¹ D. Alastair Hay, “An Investigation in the Swiftiness and Intensity of Recent Secularization in Canada: Was Berger Right? *Sociology of Religion* 75:1 (2014) 1136-162.

competition was a principal catalyst for establishing the nascent Latter-day Saint movement and one reason why early Mormons chose to live in sequestered enclaves.³²

Utah was founded as an enclave. Within Utah, Mormon theology is not esoteric and marginal as it is in much of the nation.³³ Rather, it constitutes the normative view. Mormons born in the faith exceed converts 5:1 in Utah, so LDS doctrine is often inculcated from infancy.³⁴ Conversely, where Mormonism is a minority faith, the church functions without the trappings of a *de facto* establishment. Mormons in Utah are less likely than other Mormons to agree with the statement, “Some teachings of the LDS Church are hard for me to believe.”³⁵

Conflated Norms

Dense concentrations of Mormons in Utah produce associations within the denomination that extend beyond the ecclesiastical sphere. Social networks in the neighborhood, the extended family, the workplace, and civic organizations are all likely to be stocked with Latter-day Saints. This imbues interaction in otherwise secular venues with religious significance and imposes church behavioral standards on Mormons in non-church settings. The ability to observe one another in such settings promotes compliance among those who might otherwise shirk. For example, a Mormon drinking coffee at work is subject to disapproval from an LDS coworker just as if he or she was observed by someone in his or her ward. Coterminal ward and neighborhood boundaries make yard work on Sunday hard to conceal. Extensive kin networks within the faith—common among Utah Mormons but rare outside the state—conflate family and religious solidarities.³⁶

³² Patrick Q. Mason, “God and the People: Theodemocracy in Nineteenth Century Mormonism,” *Journal of Church and State* 53:3 (2011) 349-375.

³³ James K. Wellman, Jr. and Katie E. Corcoran, “Religion and Regional Culture: Embedding Religious Commitment within Place,” *Sociology of Religion* 74:4 (2013) 496-520. Gary C. Lawrence, *How Americans View Mormonism: Seven Steps to Improve Our Image*, Orange, CA: The Parameter Foundation, 2008. J. B. Haws, *The Mormon Image in the American Mind: Fifty Years of Public Perception*, New York: Oxford University Press, 2013.

³⁴ Rick Phillips, “Mormon Identity in the United States: Ascribed and Achieved Characteristics.” Paper presented at the annual meeting of the Mormon Social Science Association, Provo, UT, 2017.

³⁵ Benjamin Knoll, “Faith and Doubt in Contemporary Mormonism: A Quantitative Empirical Perspective,” Paper presented at the Salt Lake City Sunstone Symposium, Salt Lake City, 2016.

³⁶ For an extended discussion, see Phillips, “Saints in Zion, Saints in Babylon.”

Using ward rosters as a sampling frame, Brigham Young University sociologist Marie Cornwall found that Mormon majorities in Utah fostered greater obedience to observable church mandates (like meeting attendance) but were not associated with higher levels of private religiosity (like frequency of prayer).³⁷ Albrecht makes a similar observation, describing a subset of Utah Mormons as “ritualists,” who “participate in the various social activities of the church but who are weak in terms of their doctrinal conversion and faith.”³⁸ Other religious subcultures with similar characteristics have been described. For example, Sherkat and colleagues call African-American churches in the rural South “semi-involuntary institutions,” because they must assume some civic functions to compensate for systemic racism.”³⁹

Subcultural Vitality

The vitality of Utah’s religious subculture is proportional to the density of Mormons in a given locale. For example, a study using data from 1980 found that among Utah counties there was a positive, linear relationship between the percentage of a county that is LDS and rates of church activity in that county.⁴⁰

Of course, there is no incongruity between private devotion and public behavior for most Utah Mormons. For most, Utah’s religious subculture doesn’t coerce their compliance but rather reflects their commitment. But this robust subculture has also provided a hedge against

³⁷ Marie Cornwall, “The Social Bases of Religion: A Study of Factors Influencing Religious Belief and Commitment,” *Review of Religious Research* 29 (1987) 44–56. Marie Cornwall, “The Influence of Three Agents of Religious Socialization: Family, Church and Peers,” in *The Religion and Family Connection: Social Science Perspectives*, ed. Darwin L. Thomas, 207–231. Provo, UT: Religious Studies Center, Brigham Young University, 1988. Marie Cornwall, “The Determinants of Religious Behavior: A Theoretical Model and Empirical Test,” in *Latter-day Saint Social Life: Social Research on the LDS Church and Its Members*, ed. James T. Duke, 345–372. Provo, UT: Brigham Young University Religious Studies Center, 1998. Marie Cornwall and Darwin L. Thomas, “Family, Religion, and Personal Communities: Examples from Mormonism,” *Marriage and Family Review* 15 (1990) 229–252.

³⁸ Albrecht, “The Consequential Dimension of Mormon Religiosity,” 269.

³⁹ Darren E. Sherkat, “Embedding Religious Choices: Integrating Preferences and Social Constraints into Rational Choice Theories of Religious Behavior,” in *Rational Choice Theory and Religion: Summary and Assessment*, ed. Lawrence A. Young, 65–85. New York: Routledge, 1997. Darren E. Sherkat and Shannon A. Cunningham, “Extending the Semi-Involuntary Institution: Regional Differences and Social Constraints on Private Religious Consumption among African Americans,” *Journal for the Scientific Study of Religion* 37:3 (1999) 383–396. Christopher G. Ellison and Darren E. Sherkat, “The ‘Semi-involuntary Institution’ Revisited: Regional Variation in Church participation among Black Americans,” *Social Forces* 73:4 (1995) 1415–1437.

⁴⁰ Phillips, “Religious Market Share and Mormon Church Activity,” 122–125.

inactivity and defection for those who have little intrinsic desire to conform, because inactivity and defection have traditionally incurred social costs beyond the ecclesiastical sphere.

The concentration of Mormons in Utah intensified throughout most of the 20th century. In 1920, Utah was 61% LDS. In 1990, it was 77% LDS.⁴¹ The Mormon preference for large families outstripped the fertility and in-migration of other religious groups.⁴² Several Utah counties were over 80% LDS throughout the last half of the 20th century.⁴³ This demographic concentration, and the subculture it sustains, explains the church's high retention rate in the Rocky Mountain states in the 20th century observed in Figure 1.

Mormon Majorities and Demographic Flux

Data on the demographic characteristics of Mormons are published by the LDS Church and found in various polls and surveys conducted by social scientists. Utah data are sometimes used to make inferences about Mormons in the state.⁴⁴ Understanding some aspects of Mormon demography involves piecing together information from various sources. Data released by the LDS Church are usually based on membership rosters. People who join the church are generally not expunged from these rosters until they die, regardless of their level of activity.⁴⁵ Even those who have joined other churches are typically not removed. For this reason, there are many people on church rolls who no longer self-identify as Mormons. By contrast, most polls and surveys conducted by social scientists

⁴¹ Phillips, "Saints in Zion, Saints in Babylon," 8.

⁴² Tim B. Heaton, "Demographics of the Contemporary Mormon Family," *Dialogue: A Journal of Mormon Thought*, 25:3 (1992), 19-34.

⁴³ Rick Phillips, "The 'Secularization' of Utah and Religious Competition," *Journal for the Scientific Study of Religion*, 38:1 (1999) 72-82.

⁴⁴ Tim B. Heaton, "Four Characteristics of the Mormon Family: Contemporary Research on Chastity, Conjuality, Children, and Chauvinism, *Dialogue: A Journal of Mormon Thought*, 20:2 (1987) 101-114. Arland Thornton, "Religion and Fertility: The Case of Mormonism," *Journal of Marriage and the Family* 41:1 (1979) 131-142. Tim B. Heaton, "The Demography of Utah Mormons," in *Utah in Demographic Perspective*, ed. Thomas K. Martin, Tim B. Heaton and Stephen J. Bahr, pp. 181-193. Salt Lake City: Signature Books, 1986.

⁴⁵ Rarely, members are excommunicated by a church court, and some have their names removed via a formal resignation process. According to the church, excommunication and formal resignation account for less than one tenth of one percent of church members. See: Tad Walch, "A Conversation with Mormon Singles on Capitol Hill in the Era of the 'Nones,'" *Deseret News* March 30, 2017. Church members whose whereabouts are unknown are removed from church records when they reach their 110th birthday. See Rick Phillips, "Rethinking the International Expansion of Mormonism," *Nova Religio: The Journal of Alternative and Emergent Religions*, 10:1 (2016) 52-68.

are based on the respondent's self-identification. The number of Mormons on official membership rosters exceeds the number of self-identified Mormons.⁴⁶ Collectively, these data suggest that the demographic base that undergirds Utah's religious subculture is eroding. This erosion began in the late 20th century with declining Mormon birth rates and an influx of non-Mormons.⁴⁷

Mormon birth rates have exceeded the national average.⁴⁸ For decades, Utah had the nation's highest birth rate because of the concentration of Mormons in the state.⁴⁹ However, in 2017, demographers reported that Utah's birth rate had declined for the eighth consecutive year.⁵⁰ In 1980, Utah women had 1.5 more children than the national average. In 2016, this gap had narrowed to .4 more children. Utah no longer has the nation's highest birth rate.⁵¹ This is largely due to fewer births among Mormon women.⁵²

A recent influx of non-Mormons can be inferred by examining changes to Utah's ethnic makeup. In a 2008 survey, 95% of Utah Mormons were white.⁵³ The state's non-white population more than tripled between 1975 and 2008, going from about 6% to about 20%.⁵⁴ By inference, most of these people are not LDS.

⁴⁶ Phillips, "Rethinking the International Expansion of Mormonism," 54-56. David G. Stewart, *The Law of the Harvest: Practical Principles of Effective Missionary Work*. Henderson, NV: Cumorah Foundation, 2007.

⁴⁷ Michael B. Toney and Young-Taek Kim, "The Role of Migration in Changing and Sustaining Utah," in *Utah at the Beginning of the New Millennium: A Demographic Perspective* eds. Cathleen D. Zick and Ken R. Smith, pp. 56-63. Salt Lake City: University of Utah Press, 2006.

⁴⁸ William D. Mosher, Linda B. Williams, and David P. Johnson, "Religion and Fertility in the United States: New Patterns," *Demography* 29:2 (1992):199-214. Tim B. Heaton and Sandra Clakins, "Family Size and Contraception Use among the Mormons: 1965-1975," *Review of Religious Research* 25:2 (1983) 297-314.

⁴⁹ Tim B. Heaton, "Birth Capital of the Nation," in *Utah in the 1990s: A Demographic Perspective*, ed. Tim B. Heaton, Thomas A. Hirschl, and Bruce A. Chadwick, 31-40. Salt Lake City, UT: Signature Books, 1996.

⁵⁰ Kem C. Gardner Policy Institute, "Utah Demographics Fact Sheet" 2016. Accessed November 14, 2018, at <http://gardner.utah.edu/wp-content/uploads/2016/02/Fact-Sheet.pdf>.

⁵¹ Center for Disease Control, "National Vital Statistics Reports," Volume 67, Number 1, January 31, 2018. Accessed November 14, 2018, at https://www.cdc.gov/nchs/data/nvsr/nvsr67/nvsr67_01.pdf.

⁵² Tim B. Heaton, "Vital Statistics," 111-114. See also Tim B. Heaton, "Religious Influences on Mormon Fertility: Cross-National Comparisons," in *Latter-day Saint Social Life: Social Research on The Church of Jesus Christ and Its Members*, ed. James T. Duke (Provo, UT: Religious Studies Center, 1998), 425-40.

⁵³ Phillips and Cragun, "Mormons in the United States 1990-2008," 7.

⁵⁴ "Utah Demographics Fact Sheet" 2016.

Decreasing fertility and in-migration began to erode the Mormon majority in Utah around 1990. As Mormon majorities declined, the salience of the state's religious subculture waned in power and scope.⁵⁵ As non-LDS Utahns became more common in classrooms, offices, neighborhoods, and civic organizations, there was less overlap between LDS and secular norms. Latter-day Saints who were not constrained by their personal religious commitments were less concerned about being seen wearing apparel incompatible with temple garments, or putting coffee in a shopping cart, or shopping on Sunday, because fewer of their associates would regard these things as theologically significant.⁵⁶ As a result, the "ritualists"—who were never fully committed to a strict Mormon lifestyle—began to leave the church rather than conform for social reasons. This further reduced the Mormon majority, initiating a feedback loop.

Between 1990 and 2013, the Mormon share of Utah's population fell from 77% to 63%.⁵⁷ Salt Lake County—with over a third of the state's residents—declined from 63% Mormon in 1990 to 51% in 2013.⁵⁸ These figures are based on church membership rosters and not on self-identification. Thus, many Utahns who have left the church but remain on the rolls are included in these tallies. The 2016 American Values Atlas—the largest census of American religion ever undertaken—finds that self-identified Mormons constitute just 51% of Utah's population.⁵⁹ That is down from 57% in the 2008 American Religious Identification Survey, and from 69% in the 1990 National Survey of Religious Identification—two large censuses of religion that use self-identification.⁶⁰ For decades, Utah ranked 50th among states in religious diversity. It now ranks 45th.⁶¹

Nonreligious and Self-Identified Mormons

One manifestation of defecting "ritualists" is a rise in the number of Utahns with no religious affiliation. Scholars have found that when Latter-day Saints leave their religion, they are unlikely to switch to a different one.⁶² Mormon doctrines are distinctive and the switch from

⁵⁵ Phillips and Cragun, "Legacy of the 'Gathering,'" 77-94.

⁵⁶ Phillips, Cragun and Kosmin, "Increasing Sex Ratio Imbalance among Utah Mormons," 9-13.

⁵⁷ Matt Canham, "Mormon Populace Picks Up the Pace in Utah," *Salt Lake Tribune* December 2, 2014.

⁵⁸ Matt Canham, "Mormon Populace Picks Up the Pace in Utah."

⁵⁹ Public Religion Research Institute, "America's Changing Religious Identity," 42.

⁶⁰ Phillips and Cragun, "Mormons in the United States, 1990-2008," 2.

⁶¹ Public Religion Research Institute, "America's Changing Religious Identity," 13.

⁶² Darren E. Sherkat, *Changing Faith: The Dynamics and Consequences of Americans' Shifting Religious Identities*, New York: New York University Press, 2014, pp. 50-90. For a general discussion of the relevant issues pertaining to religious switching, see: Darren E.

Mormonism to mainstream Christianity is more dramatic than switching between mainstream denominations. For example, the Mormon concepts of deity and the afterlife are substantially different than those found in Catholicism or the nation's largest Protestant sects.⁶³ Because so little of Mormonism can be exported, Mormons who leave their church generally abandon organized religion. One recent survey found that more ex-Mormons had abandoned religion than had switched to all other denominations combined.⁶⁴ Another found that there are more Utahns with no religion than belong to any other denomination save the LDS Church.⁶⁵ Exit polls conducted in Utah reveal a recent rise in the nonreligious. Between the 1996 and 2008 elections, the percentage of Utah voters with no religion nearly doubled, from 9.7% to 18.5%.⁶⁶ By the 2016 election, this number had risen to 30%.⁶⁷

The coincident increase in defectors from Mormonism and people with no religion in Utah suggests that Mormons who have heretofore maintained their membership in the LDS Church because of the state's religious subculture are now freer to leave. This trend in Utah appears to be microcosmic of a nationwide phenomenon. One study concludes:

“[T]he gradual weakening of social disincentives against non-religiously affiliated individuals may be leading to a historical situation which provides those who belong but do not believe with the opportunity to finally express their true preferences without penalty. The growth of the religious “nones” could potentially be understood as a result of the waning influence of religion on social institutions.”⁶⁸

Sherkat, “Tracking the Restructuring of American Religion: Religious Affiliation and Patterns of Religious Mobility, 1973–1998,” *Social Forces* 79:4 (2001): 1469. Paul Sullins, “Switching Close to Home: Volatility or Coherence in Protestant Affiliation Patterns,” *Social Forces*, 72:2 (1993) 399–419. Matthew T. Loveland, “Religious Switching: Preference Development, Maintenance, and Change,” *Journal for the Scientific Study of Religion* 42:1 (2003) 147–157.

⁶³ See Donald W. Musser and David L. Paulsen (eds.) *Mormonism in Dialogue with Contemporary Christian Theologies*. Macon, GA: Mercer University Press, 2007.

⁶⁴ Pew Research Center, “America’s Changing Religious Landscape,” 39.

⁶⁵ Public Religion Research Institute, “America’s Changing Religious Identity,” 42.

⁶⁶ These exit polls are online at exitpolldata.byu.edu.

⁶⁷ Paul A. Djupe, Jacob R. Neihsel and Kimberly Conger, “Are the Politics of the Christian Right Linked to State Rates of the Nonreligious? The Importance of the Salient Controversy,” *Political Research Quarterly*. 71(4): (2018) 910–922.

⁶⁸ Jason Wollschleger and Lindsey R. Beach, “Religious Chameleons: Exploring the Social Context for Belonging Without Believing,” *Rationality and Society* 25(2): (2013) 192.

Examining the church activity of Mormons who have remained in the church throughout this period of waning religious influence bolsters the hypothesis that defectors were typically less committed to the church's lifestyle demands. Recent surveys show that self-identified Mormons are among the most observant of all Christians. Between 2007 and 2014—a time of increasing defection from the faith in Utah and parts of adjacent states—the percentage of self-identified Mormons who reported daily prayer and regular scripture reading remained stable.⁶⁹ Weekly church attendance among self-identified Mormons also remained stable during this interval, at 76% in 2007 and 77% in 2014.⁷⁰ This combination of indicators is informative, because they measure both private and social religious behavior.

The rapid rise in people with no religion in Utah and the sustained, robust church activity of self-identified Mormons casts doubt on the claim that troubling facts about Mormonism on the internet are a principal catalyst for defection, because this claim cannot explain the regional disparities in defection observed in Figure 1.

Conclusion

I have argued that a sharp rise in defections from Mormonism in Utah and parts of adjacent states is not strongly linked to internet use as some activists and journalists assert. Instead, I contend that increasing defection among Utah Mormons is primarily caused by the least committed members of the LDS Church choosing to sever whatever ties exist between themselves and the organization. This choice is less socially costly than in previous decades, because the state's religious subculture is less able to define public norms than it was a generation ago. This dynamic conforms to what sociologists know about the nonreligious more generally. According to one study, those who forsook religion "were recruited from among people who had weak religious attachments to begin with."⁷¹

Nevertheless, anecdotal accounts of devout Latter-day Saints who apostatize in the manner set forth by the activist explanation are sufficiently abundant that they must be considered. Moreover, there is preliminary evidence that the advent of the internet and the concomitant rise

⁶⁹ Pew Research Center, "U.S. Public Becoming Less Religious, 13.

⁷⁰ Pew Research Center, "U.S. Public Becoming Less Religious," 11, 13.

⁷¹ Michael Hout and Claude S. Fisher, "Explaining why More Americans Have No Religious Preference: Political Backlash and Generational Succession, 1987-2012," *Sociological Science*, 1 (2014) 423-447.

of the nonreligious nationwide have some causal connection.⁷² Websites that attack the theological foundations of Christianity that are similar in form to those critical of Mormonism proliferate online.⁷³ In one recent survey, about 60% of the nonreligious listed losing belief in the tenets of their faith as an important reason for forsaking religion, and information on the internet could be a source of doubt.⁷⁴ If this is true, it follows that this nationwide phenomenon would manifest within Mormonism as well. This could explain the increase in defection from 23.9% to 31.5% observed outside the Intermountain West in Figure 1.

Rising defection has been met with alarm by LDS leaders and cheered by the church's critics.⁷⁵ But the departure of the "ritualists" is not necessarily bad news for the church. Sociologists of religion have found that when less-committed members of a religious organization depart, it raises the mean level of commitment and activity among those who remain and allows the organization to invest resources in people who are more likely to give back at least as much as they take.⁷⁶

Ethnographic studies show that Latter-day Saints living outside the Intermountain West often criticize Utah's religious subculture and express dismay at the disjunction between orthodoxy and orthopraxy they observe among the "ritualists" in the state.⁷⁷ Utah Mormons are commonly accused of having shallow commitments and of taking the church for granted.⁷⁸ One BYU scholar warns that "it is important to distinguish between... 'cultural Mormonism,' which is based on Mormon culture and conversations, and 'doctrinal Mormonism,' which is based on the

⁷² McClure, "Tinkering with Technology." Allen B. Downey, "Religious Affiliation, Education and Internet Use," March 2014. Accessed November 14, 2018, at <https://arxiv.org/pdf/1403.5534.pdf>.

⁷³ For example, the atheism forum on the popular discussion site Reddit has over two million subscribers.

⁷⁴ Public Religion Research Institute, "Exodus," 7.

⁷⁵ Heidi Hatch, "Millennial Mormons Leaving Faith at Higher Rate than Previous Generations," KUTV News, Wednesday, April 13, 2016. Accessed November 14, 2018, at <http://kutv.com/news/local/millennial-mormons-leaving-faith-more-than-previous-generations-are-more-republican>. See also: Heidi Hatch, "Losing Their Religion: Millennials, including Utahns, Leaving Church," KUTV News, Wednesday, May 10, 2017. Accessed November 14, 2018, at <http://kutv.com/news/local/losing-their-religion-millennials-including-utahns-leaving-church>.

⁷⁶ Laurence R. Iannacone, "Why Strict Churches are Strong," *American Journal of Sociology* 99:5 (1994) 1180-1211.

⁷⁷ Christine Horne, *The Rewards of Punishment: A Relational Theory of Norm Enforcement*. Palo Alto, CA: Stanford University Press, 2009, p. 43.

⁷⁸ Clark S. Knowlton, "Social Accommodation in Utah," in *Essays on the American West, 1974-1975*, ed. Thomas G. Alexander, 79-108. Provo, UT: Brigham Young University Press, 1976, p. 91.

scriptural, canonized theology of the Church.”⁷⁹ But recent trends suggest that the loose correlation between belief and behavior traditionally observed in Utah is tightening, and rates of church activity among self-identified Mormons are becoming more homogenous across the nation.⁸⁰ One manifestation of this homogeneity is the similar rate of defection among all Mormons observed since 2000 in Figure 1.

Finally, just as Mormons are not evenly distributed across the nation, they are not evenly distributed within Utah. By 2020, Mormons will likely lose their majority in some populous counties, including Salt Lake County. Other populous counties still have Mormon supermajorities, such as Cache County (74% LDS) and Utah County (83% LDS).⁸¹ The hallmark features of Utah’s religious subculture will likely be preserved in these counties for some time. However, demographic projections suggest that Mormon majorities will continue to dwindle throughout the state.⁸² Given this, the best prediction based on current trends is that as the religious demography of Utah comes to resemble the religious demography of a typical state, the church activity of Utah Mormons will come to resemble the church activity of Mormons in a typical state.

⁷⁹ Sarah Harris, “Many Struggles with Faith Are Based on Mormon Culture, Not Doctrine, Professor Says,” *Church News*, August 24, 2017.

⁸⁰ Rick Phillips, “Sources of Mormon Religious Activity in the United States: How Latter-day Saint Communities Function where Mormons Predominate, and Where They Are Sparse,” *Journal of the Utah Academy of Sciences, Arts and Letters*. 91 (2015) 259-276.

⁸¹ Matt Canham, “Mormon Populace Picks Up the Pace in Utah.”

⁸² Samuel M. Otterstrom, “Divergent Growth of The Church of Jesus Christ of Latter-day Saints in the United States, 1990–2004: Diaspora, Gathering, and the East-West Divide,” *Population, Space and Place* 14 (2008) 231–252.

Thereby Throw Sand: Presidential Media Respect through Honorific. References in White House Press Briefings, 2001-2017

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Abstract

The Media have been accused of being collectively and individually opposed to President Donald Trump, while simultaneously exhibiting disrespectful behavior coupled with barely controlled contempt. If the Media are the “opposition party,” as President Trump’s former adviser Stephen Bannon claimed, then the nerve center might be the pressroom at the White House. How might this opposition to the 45th president be most apparent? Perhaps by neglecting to give Mr. Trump the honorific of “president” when referring to him. It is the purpose of this study to determine whether over 16 years and the past three presidents (Bush, Obama, Trump) respect for the president has declined as measured by the presidential honorific accorded him at White House press briefings held by each president’s first press secretaries (Fleischer, Gibbs, Spicer) in their first few months. It finds little real difference between them, although President Trump is actually treated slightly more favorably.

“Moving parts in rubbing contact require lubrication to avoid excessive wear. Honorifics and formal politeness provide lubrication where people rub together. Often the very young, the untravelled, the naive, the unsophisticated deplore these formalities as “empty,” “meaningless,” or “dishonest,” and scorn to use them. No matter how “pure” their motives, they thereby throw sand into machinery that does not work too well at best.”
 – Robert A. Heinlein¹

The Media have been accused of being institutionally and individually opposed to President Donald Trump, while simultaneously exhibiting disrespectful and distrustful behavior with barely controlled contempt. This study examines simply how often White House press corps reporters use the honorific “President” when referring to Presidents Donald Trump, Barack Obama, and George W. Bush at the daily briefings.

If, indeed, the Media are the “opposition party,” as President Trump’s former top adviser Stephen Bannon has claimed, then its nerve center might be the pressroom at the White House and its cadres would be the many dozens of reporters crammed into it for the daily White House press feeding frenzy (Grynbaum, 2017).² And how might this opposition to the 45th president be most apparent? Perhaps by neglecting to give Mr. Trump the honorific of “President” when referring to him. It is the purpose of this study to determine whether respect for the president declined over 16 years as measured by the presidential honorific accorded him at the invariably combative and frequently acrimonious White House press briefings held by the first press secretaries of Presidents Obama, Bush, and Trump: Ari Fleischer, Robert Gibbs, and Sean Spicer, respectively.

I. Method

To test this thesis, the transcripts of the 6-12th daily press briefings were analyzed during the presidents’ first term. These were conducted by President Bush’s press secretary Ari Fleischer in Jan.-Feb. 2001, President Obama’s press secretary Robert Gibbs’s briefings in Feb.-March

¹ Robert A. Heinlein, *Time Enough for Love: the Lives of Lazarus Long* (New York: Putnam, 1973), 245.

² Bannon’s full quote is: “The media here is the opposition party. They don’t understand this country. They still do not understand why Donald Trump is the president of the United States.”

2009, and the corresponding half-dozen by President Trump's press secretary Sean Spicer from Feb.-March 2017. The transcripts were obtained from the White House archives online. Transcripts for all of the first 12 press briefings by the press secretaries for President Obama and President Bush's were archived online by the White House, but Spicer's first six were not available. A request to the White House Press Office did not elicit a response or the missing six briefing transcripts.

Press conferences for Presidents Trump, Obama, and Bush are the only three archived at the White House online. If press conference transcripts for other presidents exist, they would probably be cached at the various presidential libraries. In all, there were 1,184 minutes or 19.73 hours of transcripts reviewed for this study.

The terms searched were: "President Trump," "President Trump's," "Trump," "Trump's," "President Bush," "President Bush's," "Bush," "Bush's," "President Obama," "President Obama's," "Obama," and "Obama's." The honorific "Mr." was also searched, yielding just two results: "Mr. Trump" and "Mr. Bush." President Obama was not referred to as "Mr." in any of the briefings studied. The following terms were also left out of the dataset, since they were not, strictly speaking, honorifics: "then-candidate Trump," "the Bush administration," "President-elect Obama," and corresponding references to the other presidents in the study. Also eliminated from the study were: Trump-state Democrats, Bush Plan, Bush Proposal, Gov. Bush, Sen. Obama, Donald Trump, Barack Obama, Obama for America, and Obama transition staff. Any mention of vice president in any form was also deleted, since the study was limited to presidential honorifics. In fact, there were just a few references to the vice president in the transcripts.

II. Theory

To test the affective power of words, such as honorifics, we turn to agenda setting, priming, and framing theories. Walter Lippmann entitled a chapter in his 1922 book *Public Opinion*, "The World Outside and the Pictures in Our Heads" (Lippmann, 1922). McCombs and Shaw hypothesized in their seminal 1972 article that the media "influence[ed] the salience of attitudes" toward political issues (McCombs & Shaw, 1972, 177). The media placed Lippmann's pictures into the opinion process through cognitive processes (Dearing & Rogers, 1996). Bernard Cohen declared that the press "may not be successful much of the time in telling people what to think, but it is stunningly successful in telling its readers what to think about" (Cohen, 1963), an observation McCombs' and Shaw's empirical, correlational data buttressed. In addition to identifying

the issues, media also tell audiences “how to think about” those issues (McCombs & Shaw, 1993).

In the 1990s, agenda-setting research spread out to include priming, framing, political advertising (Roberts, 1992), and the effects on subsequent behavior of agenda setting (Brosius & Kepplinger, 1992). Dietram Scheufele (2000, 298) called framing, priming, and agenda setting three separate, but related approaches that “cannot be combined into a simple theory just for the sake of parsimony.” Framing concentrates on the presentation of the topics the media have placed on the political agenda. Iyengar and Kinder (1987, 114) defined media priming as “drawing attention to some aspects of political life at the expense of others,” since even the most educated cannot access all information. As a subset of agenda setting, framing is the selection by the media of particular aspects (attributes) of an issue, making some more important than others. Presidential honorifics slot into this category. It owes its genesis to Harold Lasswell’s description of “attention frames” and his belief that there was a correlation among media, audience, and politicians (Lasswell, 1948). There are really two types of frames: media and audience, though the process of framing encompasses both.

A new fourth level

McCombs, Guo, and Vu proposed a network agenda-setting model underlying a Level Three, contending that media can bundle conglomerations of objects and attributes (Levels One and Two) and make them salient simultaneously in audience members’ cognition (McCombs et al., 2014). In a study of famous NASCAR driver Dale Earnhardt, Shaw and Yu hypothesized that, contrary to traditional agenda setting, the media can influence audience actions not directly, but by raising the cognitive salience of an issue and then so affects the conscience or the thought process that an individual then takes some action (Shaw & Yu, 2005). That action is the result of an agenda setting trigger or affect residue that sparks action. Terry, T.C., Shaw, D.L., Ericson, B., and El-Toukhy, S. (unpublished) have expanded on this and identified it as a fourth and affective level of agenda setting (Figure 1).

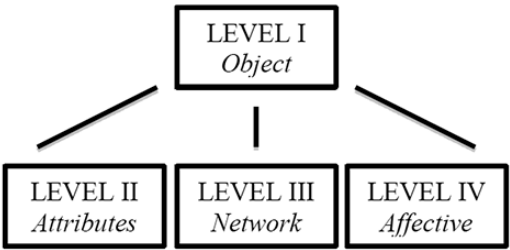


Figure 1. Four levels of agenda setting.

Earlier studies have traditionally taken a macro level view, rather than a micro one, to define the objects and attributes in news stories to identify effects; the posited fourth level of agenda setting takes it to a micro level. Content analysis procedures have typically classified objects and attributes through general key words. Rather, the grammar of agenda setting at a more granular level is at the heart of this fourth level. The honorific “President” is visible in this context. Two recent findings support this current study more broadly, both exploring the effect of specific words or aspects of language on topics. Magdalena Saldana’s investigation of the “compelling arguments” driving the salience of the unemployment issue among the public during 2011 utilized computerized content analysis to identify 76 key words (attributes) associated with the issue in *New York Times* stories (Saldana & Pain, 2015). Thirteen of these attributes function as compelling arguments with correlations ranging from .58 to .76. Marcus Funk and McCombs used 20 Diction 6.0 dictionaries to examine differences in the news coverage of the immigration and abortion issues in communities with high versus low interest in these issues. Significant differences were found in 15 different dictionaries, but only four demonstrated significant differences for both the immigration and abortion issues (Funk & McCombs, 2017).

III. Findings

The findings from an analysis of the White House press briefings are divided into two categories: honorifics used or omitted and the length of the briefings.

Honorifics

Gibbs’s first press briefing was Jan. 22, 2009 (Obama/Gibbs White House), Spicer’s was on Jan. 23, 2017, eight years later (Trump/Spicer White House), and Fleischer’s was January 14, 2001, six days before the inauguration (Bush/Fleischer White House). The six Bush/Fleischer briefings included in this study began on Jan. 31, 2009. Reporters—and the press secretaries themselves—were almost identically respectful to Presidents Obama and Trump in terms of appending an honorific. However, President Bush’s press secretary Fleischer was the biggest “offender” of omitted honorifics (Table 1). President Obama was referred to by his title 594 times in briefings 6–12, while the honorific was left off eight times for a 1.01% omission rate (Table 2). For President Bush, his title was included 625 times during the same period and neglected 8 times for a 1.28% omission rate. Reporters used the presidential honorific for Mr. Trump 657 times during Spicer’s press conferences 6–12,

Table 1. Omitted Honorific Examples*
Press Briefing by Press Secretary Ari Fleischer, 2/5/2001 #9
<i>Mr. Fleischer:</i> “Therefore they shouldn’t cut taxes—Bush shouldn’t cut taxes as much.” “That means people will pay more taxes than they are currently paying under the Bush proposal—than they would pay under the Bush proposal.”
<i>Unknown reporter:</i> “On the tax plan, Bush indicated today he was in favor of making it retroactive to the first of January. Lindsey said yesterday that Bush also favored accelerating it, which implies shifting more of the benefits into the first year of the plan. Can you kind of clarify exactly what the President would accept in terms of front-loading?”
Press Briefing by Press Secretary Sean Spicer, 2/7/2017 #9
<i>Sarah (no last name):</i> “The Ayatollah Khamenei said today that Trump has ‘helped Iran reveal the true face of America.’ He said Iran doesn’t fear Trump.”
<i>Unknown reporter:</i> “South Korean knows about [sic] Trump is a very good friend of theirs...What was [the] most important part of Trump’s policy towards South Korea?”

*Note. There were no similar exchanges involving Gibbs or a reporter that deleted the honorific more than once in an exchange. Fleischer omitted the honorific at least twice in two exchanges (both on February 5, 2001), while Spicer only deleted it more than once in one back-and-forth.

Table 2. Presidential Honorifics by Briefing			
Press Secretary	Briefing date	“President” mentions	Omissions
Fleischer	1/31/01	100	3
	2/1/01	62	0
	2/2/01	38	0
	2/5/11	113	5
	2/6/11	98	0
	2/7/01	108	0
	2/8/01	108	2
	1/29/09	96	1
Gibbs	2/2/09	92	0
	2/3/09	76	0
	2/4/09	59	1
	2/5/09	92	0
	2/6/09	107	1
	2/11/09	72	1
	2/1/17	94	2
	2/2/17	63	0
Spicer	2/3/17	64	2
	2/7/17	99	4
	2/8/17	100	0
	2/9/17	99	0
	2/14/17	138	0

Briefings lengths

Perhaps President Obama had more on his plate and his press secretary had more to discuss as the full brunt of the Great Recession crashed into the country. Perhaps Presidents Bush and Trump distrusted the press more. Perhaps Democrats like to talk more and answer more fully, while Republicans are less forthcoming and more tight-lipped. Perhaps there is some other explanation. Whatever the reason(s), press secretaries Spicer and Fleischer spent substantially less time at the White House lectern taking questions from the press corps than Gibbs (Table 3).

Fleischer/Bush

Fleischer spent an average of about half an hour taking questions at each briefing: 28.33 minutes (briefings 1–12) and 31.43 minutes (6–12). Fleischer’s briefings ranged from a very short seven minutes (his first) to a maximum of 40 minutes (twice).

Table 3. Presidential Briefings Length

Briefing	Time	Length (min)
President Bush		
1	6:10-6:17 pm EST	7
2	1:07-1:45 pm EST	38
3	1:53-2:19 pm EST	26
4	12:24-12:55 pm EST	31
5	12:37-12:56 pm EST	18
6	12:40-1:20 pm EST	20
7	1:50-2:15 pm EST	35
8	12:00-12:15 pm EST	15
9	1:12-1:50 pm EST	38
10	12:08-14:40 pm EST	32
11	2:20-3:00 pm EST	40
12	2:10-2:50 pm EST	40
President Obama		
1	1:40-2:29 pm EST	49
2	1:18-1:57 pm EST	39
3	1:42-2:32 pm EST	50
4	3:52-4:43 pm EST	51
5	1:36-2:29 pm EST	53
6	2:12-3:05 pm EST	53
7	1:49-2:35 pm EST	46
8	1:42-2:21 pm EST	39
9	2:52-3:37 pm EST	45
10	2:11-2:53 pm EST	42
11	1:38-2:27 pm EST	49
12	2:18-3:17 pm EST	59
President Trump		
6	1:43-2:32 pm EST	49
7	12:32-12:57 pm EST	25
8	12:37-1:07 pm EST	30
9	1:42-2:19 pm EST	37
10	1:48-2:38 pm EST	50
11	1:53-2:26 pm EST	33
12	1:15-2:00 pm EST	45
Briefing Averages		
Bush: 12-briefing ave.= 28.33 min; 6-12 ave. = 31.46 min		
Obama: 12-briefing ave.= 47.92 min; 6-12 ave. = 47.56 min		
Trump: 6-12 briefing ave. = 38.43 min		

Spicer/Trump

With the Trump Administration’s first five briefings unavailable, Spicer’s average for briefings 6–12 was 38.43 minutes. In total, Spicer participated in the Q&A ritual for a total of 4.48 hours (269 minutes). His briefings ranged from a low of 25 minutes to a high of 50 minutes.

Gibbs/Obama

In all, Gibbs’s time before the media was 5.67 hours (340 minutes) for briefings 1–12 and 3.67 hours for 6–12 (220 minutes). On average, over briefings 6–12, Gibbs spent 47.56 minutes answering questions. For the full 12 briefings studied, President Obama’s spokesman spent an almost identical 47.92 minutes per briefing. In all, Gibbs took 9.58 hours of questions for briefings 1–12 (575 minutes) and 5.55 hours over 6–12 (333 minutes). His briefing length ranged from a low of 39 minutes to a high of 59 minutes. Gibbs spent 9.13 minutes or 24% longer than Spicer and 16.13 minutes or 34% longer than Fleischer.

Race and the press corps?

The most dramatic difference among all three briefings is shown in Table 4. On average per minutes, President Obama was referred to 1.78 times as “President,” an honorific accorded to President Trump 2.44 times per minute and President Bush 2.85 times per minute. Perhaps the questions were longer and more complicated, befitting the economic cataclysm that occupied so much of President Obama’s first months in office.

Table 4. Honorific averages (<i>Briefings 6–12</i>)			
Press Secretary	Briefing length (min.)	“President” mentions	Ave. mentions/min.
Fleischer	220	627	2.85
Spicer	269	657	2.44
Gibbs	333	333	1.78

IV. Conclusions and Observations

So, if the press corps is biased and angry against President Trump, they are still maintaining some semblance of decorum and good manners while doing so. The premise of this study is simply not supported, that reporters in their hell-bent fury to undermine President Trump are ignoring niceties. Forgetting to call the Commander-in-Chief “President” 24 times out of 1,878 instances perhaps falls under the category of “slip of the tongue,” especially when a significant portion are committed by the

president's spokesman (Figures 2 and 3). Conclusions are dangerous and discerning motivations impossible from just a few thousand data points.

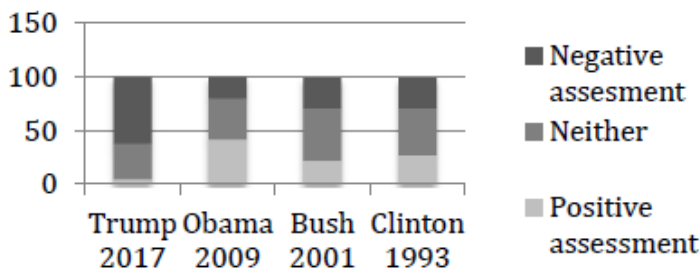


Figure 2. Presidential media story assessments. Percentage of stories about each presidency with negative, positive, and neutral assessments during first 60 days of each administration. From national newspapers, network TV shows & Newsweek. Source: Pew Research Center content analysis: "Covering President Trump in a Polarized Media Environment," Sept. 29, 2017. N: 1993=566; 2001=333; 2009=362; 2017=326.

There are also a number of potential variables neither accounted nor controlled for, given the narrow time period studied and the restricted amount of data available. Perhaps the most obvious variable is that both Trump and Bush's press secretaries' first press conferences were in the wake of very bitter and divisive elections. Maybe the composition of the Bush and Trump press corps are somehow different. Certainly, there are more nontraditional news organizations present for a typical Trump briefing than in prior administrations. Were reporters intimidated into politeness by the Trump transition team's intimations that there was no requirement that the press corps be housed in the West Wing and that a nearby building would be permissible? Are the Trump Press Corps reporters more polite because the daily briefing is routinely broadcast by CNN, rather than C-Span? This study is in line with a Pew Research Center study that looked at the past four presidents, analyzing 60 days of national network and newspaper coverage, plus *Newsweek* (Figure 2).

The most significant finding—and that is being generous—is that in Gibbs's first six press conferences, the honorific was forgotten just once by reporters when applied to President Obama during briefings that were longer as well (Figure 3). Reporters appeared more deferential to Democrat Obama, but the sample is quite small and any assumptions of political favoritism are contradicted by Fleischer's intervention and that of two reporters. Most puzzlingly, however, is the profound difference among the three presidents in honorific mentions per minute: 2.85 for

President Bush, 2.44 for President Trump, and 1.78 for President Obama (Figure 4). In a nation still grappling with race, was the White House press corps showing evidence of racial bias? Or is it simply artifactual and coincidental? Future research could expand the historical scope of this study and collect materials not in digital form at the Library of Congress, the National Archives, the White House, and various presidential libraries back to George E. Akerson, who worked for President Herbert Hoover in 1929–1930 and was the first official presidential press secretary.

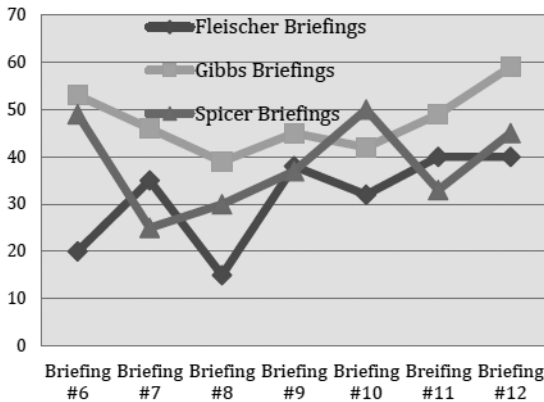


Figure 3. Length of briefings in minutes.

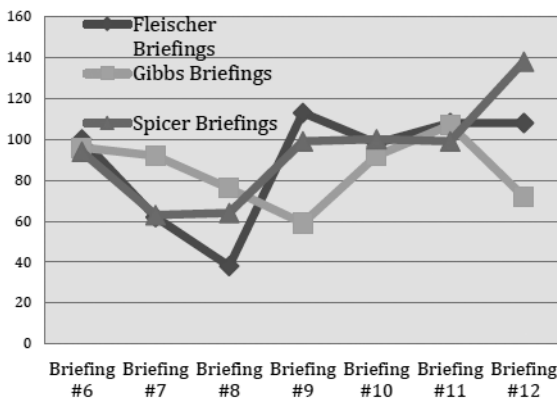


Figure 4. "President" mentions per briefing.

Reporters became generally more respectful toward Presidents Bush and Obama as time went on. However, the use of the presidential honorific soared as the march of President Trump's briefings advanced. If reporters have a vendetta against President Trump, they are largely keeping it effectively hidden or are heeding the advice of President Trump's senior adviser and campaign manager, Kellyanne Conway: "I don't sugarcoat things, but I'm very polite in delivering them."

Acknowledgments

The author acknowledges the invaluable help of Brock Damjanovich, a recent Utah State University, Logan, graduate, who assisted with the data collection and graph creation. The author also deeply appreciates the assistance of Donald L. Shaw, Ph.D., who read an earlier version of this study and made important suggestions.

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Abstracts

ARTS

Escape: A Research through Dance on the Symptoms of Addiction

Francesca DeMartino

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According to results from the 2014 National Survey and Health from the Substance Abuse and Mental Health Association, 21.5 million people over the age of 12 had a substance use disorder. This statistic of 21.5 million people represents the 8.1% of the American population that is struggling with a drug addiction. I, as an intellectual choreographer, questioned if the physical and psychological problems that an addict experiences can be translated into the formative properties of dance. In this research project, several criteria that contribute to the substance use disorder are explored through dance by working with the properties of time, space, and focus. The symptoms that are explored are withdrawal reactions, cravings, inability to cut down or control the substance use, and continued usage despite having persistent physical or psychological problems that are correlated with substance use. In this piece, I played with levels to create the up and downs that happen physically and emotionally to the users. I experimented with circle and spiral patterns to show that it is a repeated problem that also bringing the person down. I also utilized two groups of dancers to further my intent. In one group were the dancers who were experiencing the symptoms of the addiction, i.e., the users. The second group of dancers were the physical manifestation of the drugs control over the individuals, i.e., the addiction. In contrast, the individuals who represent the addiction have linear and direct movement pattern. To create a sense of uncertainty, the dancers also work with irregular accents while playing with very slow to very fast timing. It is my intention for the outcome of this piece to illuminate the struggles of an individual who is dealing with the substance use disorder through dance by playing with properties of time, space, and focus.

ARTS

Muscle Memory and Dance

Alexandria Sorenson

Utah Valley University

A fascinating characteristic of dancers is their ability to perform complex steps with specific technical requirements tied to each step. Remembering lengthy choreographic phrases with attached unique details is an ability dancers possess. Dancing requires full engagement of the brain. While dance has its own specified, complex technique, it also demands expression of emotions and connection to the world, other individuals, and the through line of dance movements. This level of multitasking is uniquely human. The incredible brain accomplishes this complex task by establishing muscle memory to remember the order of steps in choreography and the technique underlying each step. Muscle memory is organized neural pathways that achieve specific, practiced motor tasks. It leads to complex coordinated movement patterns while paying little or no attention, perhaps even thinking of something else entirely (Muscolino 105). My research will discuss the facets of muscle memory, its relationship to dance, and how it could be developed. Within this, I have also explored how to apply this to teaching dance as well as performing as a dancer.

ARTS

A Critical Analysis of the Rite of Spring by Pina Bausch Through the Feminist Perspective

Tara Meredith

Utah Valley University

Females have been the target of incessant objectification at the hand of males throughout history and spanning the world. This objectification is the means in which males oppress women to benefit and maintain patriarchy within society. Feminist critical theory is an emerging frame of analysis that seeks to expose gender roles and the existence of patriarchy, oppression, and objectification within society. It provides clear definitions of patriarchy, oppression, and objectification, and how each of them effect the welfare of women. In 1975, German choreographer, Pina Bausch, produced an evening-length modern dance piece titled *The Rite of Spring*. Objectification of the female body and

patriarchal influence are among the many themes of the piece. Patriarchy is the male-operated institution in society that focuses on the *modus operandi* of the man, leading to the deliberate oppression of women. By definition, oppression is the unjust exercise of authority or power. Patriarchy operates to express power, therefore leading to oppression of those not in power: women. Pina Bausch made the leap of awareness regarding objectification of females, and particularly the female body, through her work, *The Rite of Spring*. With the feminist perspective, one is able to observe aspects of the piece that contribute to the exposure and modes of objectification, and how the establishment of patriarchy is the direct cause of objectification. By interpreting the piece with the feminist perspective, one is also able to determine how dance reflects culture, and more specifically the cultural view on patriarchy, oppression, and objectification. Knowing that dance reflects the culture and certain cultural values allows for dance to be a valid and worthy discipline of study and critique. A critical analysis of *The Rite of Spring* by Pina Bausch through the Feminist Perspective reveals Bausch's disapproval of male objectification of the female anatomy.

ARTS

Soviets, Socialists, and the Ballet Spartacus

Arden Laga

Utah Valley University

In 1968, Russian choreographer Yuri Grigorovich created a ballet in Soviet Russia that reflected and praised its communistic governmental leadership for the 50th anniversary of the October Revolution by telling a Greek story about power, war, and victory. Critically analyzing this ballet titled *Spartacus* will show that this choreographic version was a form of propaganda to promote the Soviet political ideology and therefore Soviet culture during 1968. The post-modern critical theory of New Historicism will allow the analysis of the surrounding Russian culture and aid in understanding its influence of the production and movement choices found in the ballet. Analyzing *Spartacus* in this way will help see that this dance was used by the Soviet government to teach their belief to their people that Russia was the most powerful political force in the world during the Cold War. The methodology for this research paper will include a rigorous investigation of peer-reviewed written source material as well as a focused critical analysis using Laban Movement Analysis, a system to analyze, interpret, and notate dance and

movement, of a performance of Yuri Grigorovich's *Spartacus*. This research concludes that through the story line and the movement the ballet *Spartacus* directly reflects the political culture and the political ideology of Soviet Russia in 1968.

BIOLOGICAL SCIENCES

Rapid Method for Measuring the Effect of Prebiotics on Probiotic Bacterial Growth

Dana Hoffman, Craig Oberg, Matthew Domek

Weber State University

Prebiotics are used to stimulate probiotic bacterial growth in the gut to optimize their health benefits. A rapid method was developed to evaluate growth enhancement by prebiotics on probiotic bacteria using a programmable spectrophotometer, microtiter plates, and commercial media, with results ready in 12 hours. *Lactobacillus* strains were grown in de Man, Rogosa and Sharpe (MRS) broth while *Bifidobacterium* strains were grown in MRS broth with L-cysteine. Cultures were back diluted to an OD600 of 0.1 then inoculated into wells (48-well plate) containing individual prebiotics. Plates were placed in a Tecan Infinite M200 spectrophotometer and incubated at 37°C with A600 readings taken for 12 h. Growth curves were done in triplicate with results compared to controls to determine extent of prebiotic growth enhancement. To optimize the method, MRS concentrations of 20%, 35%, 50% and 100% were tested at selected pHs (7.0, 5.5, 5.0, 4.5, and 4.0) using 5 probiotic cultures. Addition of the bio-catalytic oxygen-reducing reagent oxyrase to the test wells significantly enhanced *Bifidobacterium* species and *Lb. acidophilus* growth. Results indicated a 25% MRS broth at pH 5.0 with 2% oxyrase optimized prebiotic growth enhancement comparisons. Using this method, the stimulatory effect of prebiotics (2% v/v) FOS, GOS, and XOS were determined for *B. infantis* M-63, *B. longum* BB536, *B. lactis* BL-04, *Lb. rhamnosus* LR-32, and *Lb. acidophilus* NCFM. All three significantly improved growth of M-63, but only FOS increased growth of BL-04. For BB536, just GOS enhanced growth. GOS and FOS slightly improved growth of NCFM while no oligosaccharides enhanced growth of LR-32. This method allows rapid testing of inoculum levels, prebiotic concentrations, media pHs, and prebiotic combinations for any probiotic strain including *Bifidobacterium*. With multiple samples run concurrently, comparisons

can readily be made to determine optimum enhancement by individual prebiotics or prebiotic combinations for any probiotic strain.

BIOLOGICAL SCIENCES

The Effects of the Anesthetic Diethyl Ether on *Dionaea muscipula* (Venus Flytrap)

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Utah Valley University

The effects of anesthetics such as diethyl ether, chloroform, halothane, isoflurane, and xenon on humans have been well known for over 150 years; however, the mechanism of these effects is unclear. This has been especially controversial when anesthetics were shown to affect plants in a similar way. Anesthetics have been shown to affect various physiological processes in plants including motility, seed germination, and chlorophyll accumulation. Specifically, anesthetics block action potentials and endocytic vesicle recycling while also inducing an exaggerated production of reactive oxygen species. At high concentration and/or long duration, anesthetics can be detrimental and sometimes fatal to mammals. In yeasts, diethyl ether can be used to selectively kill vegetative cells. The purpose of this study is to determine the effects on motility, photosynthesis rate, and respiration rate at differing concentrations of the anesthetic diethyl ether and to determine if high concentrations of the anesthetic are also detrimental to *Dionaea muscipula* (Venus fly trap). This research will shed some light on the physiological effects of an anesthetic on plants.

BIOLOGICAL SCIENCES

Isolation and Characterization of Bacteria to Degrade Art Waste Solvents

Craig Oberg, Gabriel McKay, Michele Culumber, Edward Walker

Weber State University

Paint and solvents used in acrylic and oil painting generate waste resistant to chemical breakdown, requiring expensive disposal fees, and causing health hazards during storage. Storage containers were found to contain bacteria that could be metabolizing paint waste. Microbial

degradation of three paint solvents, linseed oil, bestine, and turpenoid, by these bacterial isolates was investigated. In addition, bacteria previously isolated from jet fuel-contaminated soil were also tested for their ability to degrade these three solvents. All bacterial isolates were propagated in M9 minimal media broth containing each solvent with the majority forming biofilms at the solvent/broth interface after three weeks of incubation at 22°C. Ten of 16 isolates were identified by 16S rRNA sequencing. Isolates from paint waste containers include *Pseudomonas zhaodongensis*, *Planococcus citreus*, and *Planococcus rifletensis*. Gas chromatography mass spectrometry (GC/MS) was used to measure microbial degradation of two solvents. GC/MS results indicate six bacterial isolates degrade both bestine and oleic acid, a selected component of turpenoid, as a number of new peaks (breakdown products) were detected and initial solvent peak areas decreased over time. Results show bacterial strains isolated from paint waste and jet fuel-contaminated soil can degrade individual paint waste solvents. Optimizing growth conditions (pH, oxygen, and temperature) indicates changes in container handling can maximize solvent biodegradation to degrade paint waste, reducing disposal fees and health risks.

BIOLOGICAL SCIENCES

Micropropagation of Two Edaphic Species, *Eriogonum soredium* and *Lepidium ostleri*

Alyson DeNittis, Olga Kopp

Utah Valley University

Lepidium ostleri (Ostler's peppergrass) and *Eriogonum soredium* (Frisco buckwheat) are edaphic endemics restricted to Ordovician limestone outcrops associated with the San Francisco Mountain Range in western Utah. All known major populations primarily occur on private lands, with populations having historically sustained concentrated mining activity. Because of restricted population distribution and potential impact from modern mining operations, *L. ostleri* and *E. soredium* are currently candidate species for federal listing as threatened by the U.S. Fish and Wildlife Service. This study focuses on establishing micropropagation protocols for both species. Methods for organogenesis or embryogenesis have not been published for *L. ostleri* or *E. soredium*. Organogenetic and embryogenetic responses to different plant growth regulators were evaluated. Callus and shoot formation have been induced in *L. ostleri* on MS media supplemented with different concentrations of

IAA (indole-3-acetic acid), BAP (6-Benzylaminopurine), and kinetin (N⁶-furfuryladenine). Callus formation has been induced in *E. soredium* on MS media supplemented with different concentrations of Kinetin, 2,4-D (2,4-Dichlorophenoxyacetic acid), and NAA (1-Naphthaleneacetic acid). Further results of the effects of different plant growth regulators, media, and growth conditions will be described. Establishing micropropagation protocol for *L. ostleri* and *E. soredium* will provide valuable information for potential restoration or relocation efforts of both species.

BIOLOGICAL SCIENCES

Suppressing Growth of *Lactobacillus wasatchensis* WDC04 using Organic Acids

Ireland Green, Craig Oberg, Matthew Domek, Donald McMahon
Weber State University

Lactobacillus wasatchensis is a slow-growing, non-starter lactic acid bacterium (NSLAB) that causes late gas defect in aging cheese and results in significant economic losses to producers. During cheese aging, organic acids can be produced by other NSLAB cultures or purposefully added to cheese during manufacture. Organic acids are often used as food preservatives, can occur naturally in foods, and generally do not affect flavor or product quality. Selected organic acids, in their naturally occurring concentration ranges in Cheddar cheese, were investigated for their ability to inhibit *Lb. wasatchensis* WDC04. Five organic acids (lactic, formic, propionic, citric, and acetic) produced by NSLAB organisms were tested. They were each added at their minimum, median, and maximum concentrations, as found naturally in aged Cheddar cheese, to individual wells of a 48-well plate containing MRS broth with 1% ribose (MRS+R) inoculated with *Lb. wasatchensis* WDC04. Growth rates were determined on a Tecan Infinite 200 PRO spectrophotometer over 40 hours. Initially, tests were done at pH 7.0 with several organic acids exhibiting some inhibition. Tests were then run at pH 5.0 to determine if the organic acids were more effective at a pH of aged cheese. Both formic and citric acid showed significant inhibition of *Lb. wasatchensis* WDC04, especially at pH 5.0. Formic acid was the most inhibitory of all five organic acids with the maximum concentration (100 mM) showing the greatest inhibition. Addition of citric acid at the minimum (12 mM) and median (13.5 mM) concentrations also produced inhibition. Use of selected organic acids at concentrations normally

found in Cheddar cheese could be a potential antimicrobial measure to prevent or reduce late gas defect in aging cheese.

BIOLOGICAL SCIENCES

Synergistic Antifungal Activity of Amphotericin B, Essential Oils, and Low-Frequency Ultrasound on *Rhizopus oryzae* Bio film

Tyson Hillock, Karaleen Anderson, Mariel Hatch, Olga Kopp, Timothy Doyle

Utah Valley University

Fungal infections have gained clinical importance in the last decade. These serious and sometimes fatal infections are often associated with biofilm formation, which can increase resistance to antifungal agents when compared to free living colonies. This increased resistance makes it vital to test antifungal susceptibility using biofilms and not planktonic cells. Amphotericin B has been used as the first line of treatment for mucormycosis since the 1950s. However, it can have many adverse side effects including chills, fever, headaches, and muscle pain as well as the fatal syndromes of hepato- and nephrotoxicity. These side effects, in conjunction with mortality rates of 97% (untreated) and 39% (treated with amphotericin B), demonstrate the need for alternative treatment options. This study investigates fungal biofilm disruption in species known to cause mucormycosis using low-frequency ultrasound, amphotericin B, and essential oils. The goal of the project is to determine if low-frequency ultrasound and essential oils can be used in combination with current treatments to increase or maintain antifungal activity while avoiding the toxicity caused by high doses of synthetic drugs. The antifungal activity in essential oils originate from plant secondary metabolites, which can be classified by their phytochemical constituents. Low-frequency ultrasound treatment in combination with antibiotics has proven to be promising for biofilm removal and treatment of chronic rhinosinusitis. Ultrasound facilitates transport of antibiotics across biofilms, increases sensitivity of biofilm-growing bacteria to antibiotics, and could conceivably be used in tandem with any one or more anti-biofilm agents. We expect fungal biofilms to respond to both the disruption via the ultrasound and the antifungal properties of essential oils, thus allowing us to achieve fungal biofilm inhibition with a lower dose of Amp B.

BIOLOGICAL SCIENCES

Precision Breast and Skin Cancer Surgery with Ultrasound Instrumented Forceps

Jedediah Orullian, Tyson Hillock, Karaleen Anderson, Mariel Hatch, Timothy Doyle

Utah Valley University

The purpose of this study is to test the accuracy, sensitivity, and specificity of high-frequency (HF) ultrasound (20-80 MHz) forceps for the ex vivo assessment of margin specimens on normal and cancerous breast and skin tissue obtained from the National Disease Research Exchange (NDRI). The hypothesis for the study is that HF ultrasonic signals are capable of differentiating malignant from normal and atypical tissue in breast and skin cancer specimens. A prior feasibility study at the Huntsman Cancer Institute indicated that HF ultrasound can differentiate between normal, atypical, and malignant pathologies in breast and skin cancer surgery margins. Our goal is to further test and validate this technique for the intraoperative assessment of margins during breast cancer surgery. The specific aims of this study include the following: 1. Determine the sensitivity, specificity, and accuracy of HF ultrasound for distinguishing malignant from nonmalignant tissue in breast cancer and skin cancer biospecimens. 2. Determine the spatial resolution of HF ultrasound for measuring the proximity of malignant tissue to the margin edge. 3. Collect ultrasonic data from a total of 80 breast biospecimens to establish statistically significant results.

BIOLOGICAL SCIENCES

Comparison of Frequency, Peak Density, and Attenuation Between Large Transducers and Forceps Transducer using High-Frequency Ultrasound on Pigskin Samples

Gabriela Lizarbe, Mariel Hatch, Casey Hardy, Morgan Clawson, Timothy Doyle, Michael Salisbury, Garrett Wagner

Utah Valley University

Receiving negative margins during tumor resection surgery is incredibly important in avoiding recurrence of malignant cells. Our team has worked alongside surgeons at the Huntsman Cancer Institute to engineer

and program a pair of ultrasound instrumented forceps for the diagnostic detection of malignant tissue. The goal of the forceps transducers is to provide a tool for surgeons to instantaneously detect and remove malignant tissues during tumor resection surgery. During initial analysis, phantoms were used to determine the success of the forceps compared with large transducers on breast tissue. The phantoms were demonstrated to be a suitable alternative for the breast tissue, providing similar frequency, attenuation, and peak density. When analyzing the testing parameters against skin samples and phantoms, comparable signals for testing were insufficient. For this reason, it was not feasible to perform analytics between the two transducers in a laboratory setting because it required human skin samples to perform the data analysis. The purpose of this study is to test pigskin with high-frequency ultrasound using forceps transducers and large transducers, analyzing similarities in frequency, attenuation, and peak density between the two testing methods. Pigskin was chosen because of the similar anatomic and physiologic characteristics that are shared with humans. In addition to testing the three parameters, differences of the pigskin storage methods using Dulbecco's Modified Eagle's Medium (DMEM) and formaldehyde are being determined.

BIOLOGICAL SCIENCES

Inhibition of Pathogens by Probiotic Strains of *Lactobacillus*

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Weber State University

Many studies have characterized lactic acid bacteria (LABs), noting their potential health promoting features and encouraging their use as probiotics. This study's purpose was to identify five strains of LABs, isolated from probiotic products, by DNA analysis and to test their ability to inhibit bacterial pathogens. LABs were identified by 16S rRNA gene analysis that indicated three isolates are *Lactobacillus rhamnosus* and two are *Lactobacillus plantarum*. Two assays, the flip agar and the agar overlay assay, were used to compare the ability of LAB colonies to inhibit 5 pathogens (*Escherichia coli*, *Salmonella typhimurium*, *Shigella sonnei*, *Enterococcus faecalis*, and methicillin-resistant *Staphylococcus aureus* (MRSA)), an important pathogen that infects wounds. The agar overlay

assay indicated that all five LABs inhibited all five pathogens. In contrast, the flip agar assay showed only minimal inhibition of MRSA by 3 of the LAB cultures. To determine if the inhibitory activity was present in the LAB culture supernatants (CSs), LABs were grown in MRS broth for up to 6 days of incubation (pH 3.5). The CSs were centrifuged, filter sterilized, and tested for their ability to inhibit the 5 pathogens using a well diffusion assay. All 5 LABs inhibited all 5 pathogens as shown by zones of inhibition around the wells containing CSs. However, when these same supernatants were adjusted to pH 6.0, they lost all inhibitory activity. Importantly, non-inoculated MRS broths at pH 6.0 and pH 3.5 were not inhibitory to the pathogens, indicating that the inhibitory activity was due to LAB metabolites. Further studies are underway to determine if the inhibitory activity is due to organic acids or some other LAB metabolite.

BIOLOGICAL SCIENCES

Isolation of a *Lactobacillus wasatchensis*-like Isolate from an Aged European Cheddar Cheese

Issac Martineau, Michele Culumber, Craig Oberg

Weber State University

Lactobacillus wasatchensis WDC04, a non-starter lactic acid bacterium (NSLAB), was isolated from aged Cheddar cheese that had late gas formation. Subsequent studies have demonstrated *Lb. wasatchensis* can produce gas in culture and in experimental cheeses. *Lb. wasatchensis* has been identified in cheeses with late gas defects from geographically dispersed locations within the United States. Recently, a sample of a European Cheddar cheese with late gas defects was examined. NSLABs from the cheese were isolated on de Man, Rogosa and Sharpe agar supplemented with 1% ribose (MRS-R) anaerobically for 7 days at 30°C. Colonies with similar morphology to *Lb. wasatchensis* were selected for 16S rRNA gene sequencing, API 50 carbohydrate panels, and were observed for gas production in MRS-R broth with Durham tubes. All of the isolates selected had identical 16S rRNA gene sequences. The 16S rRNA gene had 99% sequence identity to *Lb. hokkaidonensis* strain LOOC260 and 97% sequence identity with *Lb. wasatchensis* WDC04. Unlike *Lb. wasatchensis*, the new isolate showed acid production with several carbohydrates in addition to ribose, including D-Xylose at 24 h, and methyl-D-xylopyranoside, glucose, and maltose at 48 h. This carbohydrate profile also distinguishes this organism from *Lb.*

hokkaidonensis and other related species including *Lb. suebicus*, *Lb. vaccinosus*, and *Lb. oligofermentans*. This isolate also produced gas in MRS-R broth. This isolate appears to be another member of this closely related group of lactobacilli and, like *Lb. wasatchensis*, may cause late gas defects in aged cheeses. Further genetic and physiologic characterization will provide more evidence for the geographical distribution, diversity, and environmental reservoirs for this group of organisms.

BIOLOGICAL SCIENCES

Inhibition of *Lactobacillus wasatchensis* by Bio-Protective Lactic Acid Bacteria

Craig Oberg, Sophie Overbeck, Michele Culumber, Donald McMahon

Weber State University

Late gas defects in aging cheese result in significant losses to the manufacturer. *Lactobacillus wasatchensis*, a non-starter lactic acid bacterium (NSLAB), is an important cause of late gas defect. Controlling growth of this unwanted NSLAB may be possible by incorporating bio-protective lactic acid bacteria (BP-LAB) cultures into the cheese during manufacture, which would inhibit *Lb. wasatchensis* growth during cheese aging. Previous research has shown several BP-LAB cultures inhibit *Lb. wasatchensis* to varying degrees but the extent and mode of inhibition were not determined. In addition, other potential BP-LAB strains were tested for their inhibitory capacity. Quantification of inhibition between BP-LAB cultures and *Lb. wasatchensis* was done using the spot test with the agar-flip method then measuring inhibition zones over time. MRS agar with 1% ribose (MRS-R) was inoculated with each BP-LAB and incubated anaerobically at 35°C for 48 h to form a spot colony. Inoculated agar was flipped over and a *Lb. wasatchensis* strain swabbed on the exposed surface, then plates were incubated anaerobically at 25°C for 72 h. The five most inhibitory BP-LAB cultures were *Lb. rhamnosus* LB3, *Lb. paracasei* P-210, *Lb. brevis* ATCC 13648, *Lb. casei* F19, and *Lb. paracasei* LILA. Quantification of possible synergistic inhibition by co-BP-LAB strains was tested by mixing 1 mL each of two different BP-LAB strains, and then repeating the agar-flip protocol. Four co-cultures were tested LB3/ P-210, LB3/P-220, P-200/P-210, and P-200/P-220. No significant increases in inhibition zones were observed when BP-LAB cultures were paired

versus individual strains. Results confirm selected BP-LAB strains can inhibit growth of *Lb. wasatchensis*. Initial results also suggest some BP-LAB cultures may be producing bacteriocins that inhibit *Lb. wasatchensis*. Addition of selected BP-LAB cultures during cheesemaking could control late gas defect during cheese aging.

BIOLOGICAL SCIENCES

Evaluating the Synergistic Treatment of Amp B and Cinnamon Oil on *Absidia corymbifera* Biofilms

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Utah Valley University

This study will evaluate the effectiveness of the synergistic antifungal activity of amphotericin B (amp B) and cinnamon oil on *Absidia corymbifera*, a fungus known to cause mucormycosis. Mucormycosis is a fungal disease affecting immunocompromised individuals, such as newborn, cancer, or human immunodeficiency virus patients. The disease causes headaches, coughing blood, facial swelling, scabbing, pain, and a variety of other symptoms. Amp B proves highly effective in treating fungal diseases and is the preferred treatment for mucormycosis. However, amp B treatment includes the risk of severe side effects. On the other hand, the risks of cinnamon oil treatment are fewer and less severe. Cinnamon oil contains eight identified phenolic compounds and shows antifungal and antimicrobial properties. Because of cinnamon oil's phytochemicals and lack of complications, identifying a ratio effective in treatment may prevent serious complications or even save lives. The independent variable will be a concentration range of the two treatments, high to low. Fungal biofilms will be grown in 96-well plates and then treated with the antifungal agents. Each experiment round will use three synergism plates, one amp B dilution plate and one cinnamon oil dilution plate. Amp B and oil plates will consist of three rows for duplication purposes. All biofilms will be treated with an XTT/menadione solution and absorbance measurements will evaluate cell density, which has been shown to correlate with cell activity. We hypothesize that the combination of cinnamon oil with amp B will lower the dose of amp B required to inhibit biofilm growths in *Absidia corymbifera*.

BIOLOGICAL SCIENCES

Separating Organic Material Using Microfluidic Device

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This project uses microfluidic devices to separate organic material. A microfluidic device is a tube that can prevent the mixing of liquids as they pass through. The goal of this project is to use electric currents to separate organic material within a microfluidic device. There will be a negative current on one side, and a positive current on the other. DNA, which is negatively charged, will be pulled towards the positive electrode. Proteins can vary in charge depending on type but will also be separated and pulled towards their respective electrodes. The goal of this project is to be able to use the device to separate DNA and proteins for analysis. Our goal is to use this device to analyze prehistoric animal bones, but this project could also help in the fields of forensics, medicine, and phylogenetic research. This device would be inexpensive and easy to use and could quickly separate organic materials. With this device, we would be able to make DNA analysis more accessible to universities, small businesses, etc. Six microfluidic device prototypes have already been made. With each prototype, we fix old problems and run into new ones. To make these microfluidic devices, we create the pathway with magnesium wire, which is then surrounded by polydimethylsiloxane. After the polydimethylsiloxane hardens, the device is placed in a sonicator, which dissolves the magnesium. This leaves a thin, hollow, tube for the liquid to travel. The device uses flow cell electrophoresis, which is perpendicular to flow direction. As the liquid passes through the device, the electric currents pull the materials to different sides. They are then separated through different tubes at the end of the device.

BIOLOGICAL SCIENCES

Characterization of the Hemolytic-like Activity of Probiotic *Lactobacilli*

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Lactobacilli are valued for their health promoting aspects and their use as probiotics. However, we observed in our laboratory that five probiotic *lactobacilli* (PLBs) lysed sheep blood agar (SBA), a characteristic of

pathogens. This study's goal was to characterize this hemolysis. Initially, PLBs were inoculated onto SBA, incubated at 25°, 30°, and 37°C, aerobically and anaerobically. All five PLBs lysed SBA after 2–4 days of incubation under all conditions. PLBs were then grown in broth for 2 and 6 days to obtain culture supernatants (CSs). CSs of the five PLBs were filter sterilized and pipetted onto SBA plates. After 24 hours of incubation, the SBA was lysed by all CSs, with day 6 CSs causing larger zones of hemolysis than day 2 CSs. The pH of CSs and non-cultured broth was adjusted to pH 6. These were tested along with the original CSs (pH 3.4–3.5) on SBA. All pH 3.4–3.5 CSs lysed SBA but none of pH 6 CSs lysed the SBA. Importantly, non-cultured broth did not lyse SBA at either pH, indicating that metabolites in the CSs were responsible for hemolysis. Studies are underway to characterize the chemical nature of the hemolytic activity of cultured PLBs

BIOLOGICAL SCIENCES

The Degradative Effect of Horeseradish Peroxidase on Microbial Biofilms

Samuel Kalis

Weber State University

Bacteria in nature do not grow in suspension in liquid culture as they do in the lab, but rather they grow attached to surfaces, often forming biofilms. These biofilms are typically matrices of polysaccharides, proteins, and lipids hosting a consortium of bacteria living together in a community safe from the environment at large. Biofilms not only grow in what is often thought of as nature: rocks, streams, ponds, etc., but also in places or on objects where their presence is less than desirable, e.g., indwelling intravenous catheters, endoscopes, hulls of ships, and oil or gas pipelines. In this investigation, the enzyme horseradish peroxidase was tested at a method of degrading and even eliminating biofilms formed by *Staphylococcus aureus* and *Pseudomonas aeruginosa*, species often implicated in medical contexts. Cultures of *S. aureus* and *P. aeruginosa* were grown in microwell plates to allow biofilms to form in the wells, the culture was removed, and the biofilms were subsequently treated with solutions of horseradish peroxidase and hydrogen peroxide, the substrate for horseradish peroxidase. Afterwards, the biofilms were washed and stained with crystal violet. Staining solution was washed away, and the crystal violet bound to biofilm was dissolved in ethanol. Absorbance of the freed crystal violet was read in a plate reader. A range

of concentrations and conditions were tested: time, temperature, concentrations of horseradish peroxidase, and concentrations of hydrogen peroxide. Also, the feasibility of reuse of the enzyme solution was tested. Currently, no conditions generated results suggestive of clearance of biofilms superior to the positive control solution. Some combinations of enzyme and hydrogen peroxide concentrations yielded clearance, but no greater than the positive control. As of now, the results from this investigation suggest that under the conditions examined horseradish peroxidase was not effective for degrading microbial biofilms.

BIOLOGICAL SCIENCES

Possible Plant Protein Identification with Honey's Proteome

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Bees are of tremendous biological importance, as they are the primary pollinators of wildflowers and most agricultural crops. Currently, not much is known about the selectivity of bee flower preferences, which would provide novel insights for agricultural beekeeping practices as well as potential biological understanding of these important and fascinating insects and their symbiotic interactions with plants. In our proteomic analysis of honey, 4 plant proteins were tentatively identified when protein extraction methods were employed that increased the Liquid Chromatography-Mass Spectrometry signal-to-noise ratio for peptides from the individual proteins within honey. These plant proteins were all from the mustard family, species *Arabidopsis thaliana*, or mouse-ear cress. *A. thaliana* is notable because it contains one the smallest diploid genomes of all flowering plants, at about 135 megabasepairs in length; and as a result, *A. thaliana* was the first flowering plant to have its genome sequenced. It is possible that proteins from other homologous plants might be reported as *A. thaliana* proteins during a proteomic database analysis because of the prominence of *A. thaliana* in the databases. Alternatively, the proteins might indeed be from *A. thaliana* itself, considering that this weed grows wild over many parts of the world. Continued research into honey's plant proteome

constitutes a new frontier of meaningful investigation that has both agricultural and biological significance.

BUSINESS

Investigating Supply Chain Literacy among College Students

Brigham Brau, Jim Brau

Brigham Young University

We extend the work of Brau, Holmes, and Israelsen (2017), which tested financial literacy, to the topic of supply chain management literacy. This paper examines the efficacy of learning sources associated with supply chain literacy in young adults. We survey nearly 1,300 college undergraduate students. The survey consists of a supply chain literacy quiz to determine the state of the participants' existing supply chain knowledge. Additionally, we gather socio-demographic data in three areas: 1) family and background; 2) formal learning activities; and 3) experiential learning activities. Our model examines supply chain literacy as a function of these three sources of learning. Supply Chain Management (SCM) literacy, the realization of SCM learning, is a poorly understood phenomenon. Unlike financial literacy, which has a fairly established literature, SCM literacy has not been covered in the academic literature as far as we have been able to find. In this paper, we follow Brau, Holmes, and Israelsen (2017) by using a similar instrument to collect independent variable data and a new SCM literacy quiz. The goal of this article is to directly address the issue of how young adults acquire SCM literacy.

BUSINESS

How Early Profitability Index Can Predict Bank Failure: Evidence from US Bank Failure during 2008-2010

Abdus Samad

Utah Valley University

The study of the early bank failure prediction is important for several reasons. Bank regulatory authorities are very interested in developing early warning systems to help predict impending bank failures. By doing

so, regulatory authorities may prevent a bank from its failure or reduce the costs of failures. Public confidence in the banking system is shaken or deteriorated when there are large bank failures. Preventing bank failure through early warnings/predictions not only saves billions of tax payers' dollars, but it also helps restore public confidence in the banking system. Thus, preventing failure, the early bank failure prediction/warning can provide stability in the functioning of financial institutions. There are several indices that bank management should examine seriously before it is too late. The return on assets (ROA) is one of them. Bank management should regularly scrutinize the movement of the ROA. This paper firstly examines bank profitability index, return on asset (ROA) in particular, and then profitability index of eight quarters. Quarter 1 through quarter 8 were regressed in the probit model on bank failure, Y_i , $Y_i=1$ is failure and $Y_i=0$ is non-failure, in determining the significant early quarter(s) in predicting the bank was declared failure. The quarterly mean ROA showed that mean ROA successively decreased during the immediate quarters of the bank failure. The statistical significance of the 5th quarter ROA, estimated in probit, suggests that the bank failure can be warned or predicted as early as one year and three months before the failure. The estimated model correctly predicts 98.74% of the U.S. banks that failed and 93.56% of the U.S. banks that survived.

BUSINESS

Diversification through Creating Brand Performance with Social Media, Deliverable

Chase Christian Jasperson, Jill Jasperson

Utah Valley University

This study focuses on social media and the positive causation effect that comes from use of social media within business entities. I have had that opportunity to run a small marketing agency over the past several months. From this experience, I have seen how social media has overarching positive effects on consumers, customers, and business organizations. Thanks to social media, businesses have been able to reach every corner of the globe, with the chance to advertise and produce content to everyone with an internet connection. From services such as Amazon, Etsy, eBay, more people from the most rural areas in the world are able to sell handmade goods to those who may not know otherwise of such offerings. Such social organizations exist and have for some

time. The primary groups available are Twitter, Facebook, Instagram, and WhatsApp. These platforms have put the power in the hands of the creator to help connect others from around the world.

BUSINESS

An Ethical Property Rights Argument for the Shareholder Wealth Maximization Theory of the Firm

Hanni L. Brau, Andrew Holmes

Brigham Young University

The conversation of shareholder wealth maximization vis-à-vis stakeholder utility maximization has a different ethical implication based on which school of thought is being used to analyze the dilemma. From a financial standpoint, shareholder wealth maximization is almost always the goal of the firm (Hawley, 1991). However, to many others, shareholder wealth maximization is unethical in that it seems to help only the shareholders. While these points of view are wildly accepted by their respective camps (Friedman, 1970; Jensen 2001, 2002), there is little work done evidencing the ethicality of shareholder wealth maximization outside of a business scope. In this paper, I will use philosophical ideology from property rights-based logic to support the business side claim that shareholder wealth maximization is ethical (Hegel, 1967, Locke, 1976). First, I will offer a literature review, including work at the forefront of this controversy. I will then analyze work by prominent philosophers. I will use both historical and contemporary thinking to explain why shareholder wealth maximization should be the goal of the firm because it is ethical.

BUSINESS

An Analysis of the Determinants of the Choice of College Major Using Survey Data

Marshall Ringwood, Jim Brau

Brigham Young University

The principal focus of this study is to identify statistically significant factors associated with university students choosing various business majors. Specifically, we consider the choice of management, accounting,

finance, and information systems. We also consider the choice between STEM and non-STEM degrees not part of the business school. We make use of a 512 observation survey taken from students at a large private university, in which students report on dozens of demographic variables. We then use logit regressions to test the impact of these demographic factors on the probability of a student choosing to major in one of the four previously mentioned business degrees, business degrees altogether, non-business STEM, and non-business non-STEM. Our study extends the work of Al-Rfou (2013) who examined the impact of variables that proxy for personal background factors and future job factors, along with other demographic control variables and how they relate with the choice of business major. Al-Rfou showed that the strongest personal correlates of major choice are parents, siblings, and friends. For future job factors, she provided evidence that prestige, money, and job opportunity are the most significant factors. We extend Al-Rfou's work by using US students (as opposed to students from Jordan), by including a more carefully constructed demographic control panel, and by including non-business majors. Our results provide a rich description of the factors that US students consider when choosing their majors and allows us to compare US and Jordanian students.

BUSINESS

Predicting Commercial Success of Video Games Based upon Objective Biometric Measures

Chris L Wasden, Janette Vazquez, Julio Cesar Facelli

University of Utah

Technological progress in hardware and software has powered the growth of the global video game market to over \$100 billion, making it the largest segment of the entertainment industry. At the same time, innovations in wearables and biometrics have enabled an unprecedented level of measurement and data collection of object data on human emotions, behavior and thoughts. Increasingly, the entertainment industry has begun exploring how to use objective biometric data to measure the engagement of consumers with their media products to improve their design, performance, outcomes and engagement. Also, given the growing cost for developing digital entertainment, producers are interested in using these biometric measures to better predict the success of their products and improve their engagement. The purpose of this study is to use biometric data, in the form of heart rate, galvanic skin

response, and facial expression, to objectively measure the engagement of video game players and to see if objectively gathered biometric measures of engagement can more accurately predict the commercial success of a video game than traditional paper surveys given at the time of game play. To test our hypothesis, we recruited 38 students to play 10 minutes of each of three different video games within the same genre that have published three different levels of known commercial success. We then compared a traditional and validated paper survey measure of video game engagement with biometric measures of engagement to the known commercial success of each game to measure correlations and regressions. Our findings indicate that biometric measures of engagement are significantly more accurate than paper surveys in measuring engagement and in predicting the relative commercial success of a video game. These findings could lead to improved game design and decreased commercial failures of new video games.

BUSINESS

Examining Employing Onboarding Best Practices in a Higher Education Environment

Kailey Sherman, Ryan Stephenson, Jonathan Westover

Utah Valley University

Specific onboarding practices vary across organizations depending on industry type; however, similar methods and patterns of onboarding are shared. While vast amounts of information exist regarding how organizations carry out their own onboarding processes, little research has been conducted to evaluate the effectiveness of them. Organizations would be wise to invest their resources and time in creating and executing proven effective onboarding practices for new hires on their team to improve employee effectiveness and firm profitability, as well as increase job satisfaction for their employees. This paper will focus on the higher education industry, which has scarcely been assessed by scholars. Four focus groups will be conducted composed of recently hired faculty members and their supervisors at a local regional teaching university. The current program is to be evaluated and modified based on previous research and focus group data. Recommendations will be provided to the university to better understanding what makes their onboarding program successful or poor, and in effect provide applicable information for the entire higher education industry.

BUSINESS

Accountants, Block Chain, and Bitcoin: Changing the Profession with Advancing Technology

Chelsea Dye, Ron Mano, Jennifer Harrison

Westminster College

Emerging technologies have impacted most professions in the business world in significant ways. However, the structure of accounting has remained largely consistent since Luca Pacioli published his work codifying the double-entry accounting system in 1494. In the last decade, the concept of cryptocurrency and leader Bitcoin has brought with it Block Chain technology and the possibility of drastically changing the role of accountants. Block Chain is essentially a ledger that continually updates a record of economic transactions on a peer-to-peer network. The decentralized data storage makes Block Chain a very secure technology and is thus difficult to manipulate. With the very transparent, nearly immediate, and secure record of easily trackable data, the role of accountants is rapidly changing. A permanent record with linked transactions is changing the focus of accountants to more transaction based and the role of audit is drastically changing with a high possibility of a reduced need for audit services. Accounting and financial information is developing into a real-time functionality rather than historical data, which will drastically alter the financial and accounting landscape across the globe. This article looks at the development of Bitcoin, the details of the functionality of Block Chain technology, and the changes and opportunities for accountants with the emerging technologies.

BUSINESS

A Financial Analysis of Just-in-Time Inventory Controls

Ana Johnson, Jim Brau

Brigham Young University

Brau, Fawcett, and Morgan (2007) demonstrated that supply chain management (SCM) practices add value to small firms as manifested in asset utilization, revenue generation, and competitive performance. They relied on survey results from 570 US managers to draw these conclusions. I extend the work of Brau et al. (2007) by examining a specific segment of SCM, namely, just-in-time (JIT) inventory controls

in accordance with the work of Mitra, Sundaram, and Sreedish (2012). The data sample comes from the Standard and Poor's Compustat database and provides a rich laboratory with thousands of firms and audited financial data. I begin the methods by providing summary statistics that go into great detail on the various segments of inventory control, such as raw goods, material in progress, and finished goods. I then estimate regressions by four-digit SIC code to create industry-product-specific benchmarks for inventory levels and then compute the difference between the actual inventory held by small firms and the regression-based benchmark. I use the variance on inventory as an independent variable and test to see how it correlates with the same three dependent variables of Brau et al. (2007) as well as stock returns over various horizons. This study will contribute to the lean-manufacturing academic literature (e.g., Nasab, Bioki, and Zare (2012)). Lean manufacturing is multi-dimensional and generally consists of management activities, JIT inventory management, supplier management, work teams, and quality systems. By focusing on just one of these segments of lean manufacturing, I should be able to speak directly to the impact of realized JIT on a portfolio of performance measures.

BUSINESS

Perceptions of Corporate Social Responsibility among Millennials

Brigham Brau, Jim Brau

Brigham Young University

Corporate social responsibility (CSR) literacy and perspective, the realization of CSR learning, is a poorly understood phenomenon. Unlike financial literacy, which has a fairly established literature, CSR literacy has not been covered in the academic literacy as far as we have been able to find. In this paper, we extend Brau, Holmes, and Israelsen (2017) who studied financial literacy by using a similar instrument to collect independent variable data and a new CSR questionnaire. Little is known about how individuals actually acquire CSR literacy and perspectives as the topic has not been studied yet. The goal of this article is to directly address the issue of how young adults acquire CSR literacy and perspective. Friedman (1970) argues that CSR may be seen as a tax on employees and argues this tax is unethical because employees typically do not get to vote on whether they want to lower their income to support

CSR. The school of Berle (1931), Manne (1959), and Friedman (1970) strongly feel that shareholder wealth maximization is the appropriate social norm for the goal of the firm, not CSR. However, the school of thought of Dodd (1932) and more modern-day CSR advocates support a stakeholder social norm. DeLoughy, Jin, and Drozdenko (2011) survey professionals about organizational ethics. One of their sections deals with what professionals know and feel about CSR. Our survey will survey millennials who are students instead of professionals to see the similarities and differences between the two samples.

BUSINESS

Examining Autism in the Workplace: A Focus on Vocational Organizations

Kathryn Hughes, Jonathan Westover

Utah Valley University

The UVU Autism in the Workplace project is an ongoing project that aims to find what, if any, programs and training are being used by companies in tandem with vocational organizations to better employ individuals with autism spectrum disorder (ASD). Utah has the third highest incidence of Autism Spectrum Disorder (ASD) in the country (1 in 58), with Utah County having the highest rate in Utah (1 in 40). There is said to be a tsunami of adults leaving the educational system heading into higher education and the workforce. Businesses, specifically, in our community need to critically analyze how they are currently addressing ASD in the workplace and how they will include this unique population in the future. Individuals with ASD have many talents and skills they can bring to the workforce (e.g., attention to detail, specialized focus in technology, programming), but thus far this group of individuals is grossly underemployed or unemployed. We examined the characteristics of successful ASD employment programs from companies around the United States. We found that a key characteristic every program shared was that the business had partnered with a local vocational-employment organization to assist in the creation of the program; as they have experience working with and knowing the needs of individuals with disabilities in the workplace. We then assessed the vocational resources available to Utah companies and compared those groups to the two more well-known vocational groups (PROVAIL, Ken's Krew) partnered with Microsoft and The Home Depot.

BUSINESS

An Analysis of the Number of IPOs and Publicly Traded Firms: Are We in a Crisis?

Amy Cyr, Jim Brau, Noah Brown

Brigham Young University

In December 1996, the United States had 8,025 publicly listed firms, which is the greatest number of US public firms in history (Ibrahim, 2016). Now, there are less than 4,000 publicly traded firms, less than the US capital markets had in 1976 (Rasmussen, 2017). In a recent Securities and Exchange Commission meeting, the topic was capital formation and small business, and it was argued that having 8,000 firms was better than having the 4,000 firms we have today. One of the coauthors was a panelist at this SEC meeting, and he argued that fewer firms is not necessarily a bad thing. In this paper, we test this hypothesis by examining the performance of the 4,000 firms that are no longer publicly traded versus those that are. If the portfolio of firms that no longer trade were poor investments, then in theory it is better that they delist. We use CRSP and Compustat to compute financial returns, volatility measures, and financial data metrics to examine the delisting versus remaining firms. In addition, we examine the number of IPOs today versus the peak of the late 1990s (Ewens and Farre-Mensa). Many media outlets claim the US is currently in an "IPO Crisis" (Doidge, Karolyi, and Stulz). We make similar arguments that we use for the number of publicly traded firms to support the hypothesis that fewer IPOs may actually be better for both investors and the economy. We use SDC New Issues data to test this hypothesis.

BUSINESS

Teach Me!

Shandon D. Gubler

Dixie State University

This workshop presentation addresses how a millennial pedagogy is being used to effectively motivate our college/university students to master content by teaching it, and while teaching it to real-world practitioners, develop skills and abilities they will carry with them after taking courses and beyond graduation? This "Teach Me" presentation will specifically address a pedagogical practice that enables teachers to

effectively create a sense of belonging, encourage risk-taking, and inspire creativity in their classrooms, and on-line. An emerging mindset for employers in hiring millennial students is: "Teach Me" so I can observe your technical and soft skills, enabling me to make an informed decision whether to "Hire You." An emerging mindset for students in evaluating millennial employers is: Let me "Teach You" so I can show you my technical and soft skills, and experience your corporate culture, enabling me to make an informed decision whether I want your company to "Hire Me."

BUSINESS

Taxation without Representation: Corporate Social Responsibility and Employee Compensation

**Amy Cyr, Jim Brau, Brigham Young University, Bekki Brau
University of Arkansas**

Brigham Young University

Corporate social responsibility (CSR), defined by the UN Industrial Development Organization as initiatives by firms to integrate social and environmental concerns in their business operations and interactions with their stakeholders, is a controversial topic in the management literature. Although CSR is widely discussed, unfortunately some of the potential externalities of CSR have not been studied. The goal of this project is to determine if one of these externalities, a potential decrease in employee compensation, results from increased CSR. Although motivated through agency and contracting theories, our research is mostly empirical in nature. The data come from two main databases. Employee wages and control variables are taken from Standard and Poor's Compustat database. Overall wage figures and numbers of employees are used to compute an average wage per employee at the firm and year level. We condition these numbers on industry, as different industries have different wage rates. The CSR data are taken from the Kinder, Lydenberg, and Domini's (KLD) database. The KLD data includes 159 CSR variables such as Product Safety, Climate Change, Energy Efficiency, Diversity, Corporate Governance Strength, and so forth. We follow Hillman and Keim (2001) and Baron, Harjoto, and Jo (2011) to construct a CSR composite index that serves as a proxy for the degree of each firm's CSR. The results of the Ordinary Least Squares regression show that CSR (csrcidx) does significantly impact the employee compensation above a 91% level of significance. In other

words, firms that practice CSR more aggressively also have a lower average employee wage compared with firms that did not practice CSR in the same industry and of similar size.

BUSINESS

Tourism in Utah as an Economic Development Tool

Jhana Aristondo

Utah Valley University

Tourism in Utah is largely driven by seasonal recreation at its variety of natural-heritage resources through all its seasons. This study uses empirical evidence to test different variables to examine if there is a relationship between economic development and tourism in the state of Utah. Based on recent reports published by the Office of Tourism in Utah, an average of 4 million people visit per year, which supports an estimated 18,000 jobs across the entire state. In recent years, tourists' expenditures set high records of \$8.17 billion in Utah, which has generated over \$1.15 billion in total state and local tax revenues. This study will use the non-Income Human Development Index to construct two indexes that will measure education and health to test economic development without economic growth, which is normally included in the Human Development Index. The methodology of this research uses VAR—a bivariate vector auto regression—to examine the relationship between tourism, which will be explained by taxable accommodation sales, leisure and hospitality sales, employment, real GDP and the non-Income Human Development Index between years 1990 and 2016 to determine if tourism is an economic development tool and applies the Granger Causality test to determine the causal nature of the relationship. We find evidence of tourism as an economic development tool, which not only accounts for economic growth in revenues, but the improvement of lives among Utah residents, seen through the increase in output highly dependent on human development and improvement in social well-being. The results of this study can be used by the Utah State Government to assist on budget resources on specific areas of tourism.

EDUCATION

Using Robotics to Promote Learning and Engagement in Computer Science

Suzy Cox, Chelsey Beck

Utah Valley University

Computer science is essential in our digital world. Yet the vast majority of students either choose not to study it or do not continue in the field. In many cases, this is because students do not “see themselves” as computer scientists or neglect to see how computer science can help them achieve their goals or make a difference in the world. This is particularly true for upper-elementary through high school students. Many current coding programs are too simple and detached from real-world contexts, resulting in students who see coding as a fun but useless game. Meanwhile, high school computer science courses often use complex syntax to “solve” problems from the business world (though they often reproduce existing solutions). In this session, we will explore how robotics and service-learning can be used to more effectively help students learn computer science concepts and find a place and a purpose in the field. These robotics applications invite students to explore computer science concepts in concrete ways as well as express their knowledge, identities, and concerns across content areas, bringing more cultural relevance to computer science and the assessment of other subjects. Using the Birdbrain Technologies Hummingbird platform as an example, we will explore how robotics can be employed to engage students in service, storytelling, exploration of social and environmental issues, and personal expression.

EDUCATION

Eureka Moments: Innovative Strategies to Enhance Student Thinking, Insight, and Ideas

Prent Klag

Southern Utah University

This presentation will explore how promoting and providing eureka moments for students, at all educational levels, can enhance thinking processes, generate new understandings in learning, and encourage idea development. Examples will be provided of famous “Eureka Moments”

in history and the steps and processes that led up to moments of insight. Research findings on generating eureka moments, as well as the components that make up memorable learning, will also be shared. Through a hands-on, interactive approach, participants will engage in seven strategies that can enhance the development of eureka moments. All participants will receive a packet of information.

EDUCATION

Reading Motivational Principles Fostering the Value of Reading in Young Readers

Ann C. Sharp, Douglas S. Gardner, Lorilynn Brandt, and Kristin Wright

Utah Valley University

The UVU's School of Education Faculty have met with elementary teachers in UVU's service area who express feelings of burn-out in teaching literacy. Moreover, many students themselves lose interest in reading over time (Wigfield & Guthrie, 2000) and teachers are unsure of how to address motivational issues (or unaware that they need to be addressed). An administrator from a local school district stated the problem this way: We need professional development that addresses teaching reading motivation to students, who may not struggle with technical aspects of reading, but do not choose to read and do not appear to be engaged readers. To address the dual issue of motivating teachers in teaching reading and motivating students to read, faculty from the UVU School of Education and UVU University College designed and implemented the Read-A-Difference program in two elementary schools in their local school districts. Designed to address articulated needs from our local districts, professional development assists elementary school teachers in connecting essential literacy skills with a love for reading without distracting fidelity to their required literacy interventions. Using methods based on scientific research, from Guthrie and Wigfield (2000), Marinak and Gambrell (2008), Turner and Paris (1995), and Fox (2014), Read-a-Difference professional development provides training in choice, challenge, control, authenticity, collaboration, technology, and proximate rewards. Our research produced qualitative data showing all teacher participants being influenced by a heightened positive awareness of motivational principles and practices, along with an "awestruck" realization of the power of motivational strategies being used. Struggling readers gained a new sense of accomplishment, students engaged in

voluntary reading activities in and out of the classroom, and students and teachers engaged in goal setting that inspired increased reading and a sense of greater accomplishment. Our presentation will share some of the highlights of our qualitative findings.

EDUCATION

A Historical Approach to Learner-centered Teaching

Evan Sharp

Brigham Young University

This paper intends to deepen the current research on Learner-centered Teaching (LCT), a pedagogy seeking to shift the focus of educators from their own teaching to the learning of the students. The research regarding LCT, however, focuses mainly on modern contexts. No one has looked to the past for examples of LCT in the methods of ancient educators. This paper begins the research on historical examples of LCT and opens a discussion on the comparisons that can be made between historical teaching methods and the methods included in LCT. One learning theory that plays a significant role in LCT is Constructivism. This paper illustrates the presence of constructivist learning in historical education settings through a case study analyzing some of the teaching methods of Jesus Christ. Regardless of one's belief in his historical authenticity, Jesus is an excellent example because his teachings are well-known and widely available. This paper analyzes interactions that Jesus had with others in the New Testament Gospels and makes connections between Jesus's teaching methods and those related to constructivism in LCT. The purpose of these connections is not to suggest that Jesus taught exactly as is outlined in LCT; rather, it is to show the usefulness of studying historical examples of LCT and to encourage such research. Although Jesus does not fit the modern definition of a learner-centered teacher, certain aspects of Jesus's teaching closely resemble the methods of LCT. The goal is to expand its area of research, which will undoubtedly lead to better implementation. It will also strengthen the argument for its use in modern education. Other historical teachers should be researched in this way, and connections with learning theories other than just Constructivism should be explored. This paper intends to point out this gap in current literature and call for additional research.

EDUCATION

Examining Autism in the Workplace: What are the Public Schools Doing to Prepare Future Autistic Workers?

Kathryn Hughes, Jonathan Westover
Utah Valley University

The UVU Autism in the Workplace project is an ongoing project that aims to find what, if any, programs and training are being used by companies in tandem with vocational organizations to better employ individuals with autism spectrum disorder (ASD). Utah has the third highest incidence of Autism Spectrum Disorder (ASD) in the country (1 in 58), with Utah County having the highest rate in Utah (1 in 40). There is said to be a “tsunami” of adults leaving the educational system heading into higher education and the workforce. Businesses in our community need to critically analyze how they are currently addressing ASD in the workplace and how they will include this unique population in the future. Individuals with ASD have many talents and skills they can bring to the workforce (e.g., attention to detail, specialized focus in technology, programming), but thus far this group of individuals is grossly underemployed or unemployed. We examine the weight this issue places on businesses native to Utah, rather than Utah public school systems on the basis of available funding, ASD programs already in place, and legal obligations. This project is an initial step in determining how to better support employers and employees who are looking to tap into the talents associated with ASD.

ENGINEERING

An Experiment to Evaluate the Deflection of a Beam

Jacob Carter, Ali S Siahpush
Southern Utah University

In engineering applications, when different components such as beams, columns, or foundations have been used, they are typically designed within certain limits. Limits are placed on the amount of elastic beam deflection when it is subjected to a load. The design of such beams can be complex but is to ensure the beam can safely carry the required load. In our previous paper, a device was designed and constructed to evaluate

the elastic deflection of a beam. The paper discussed the fundamentals of beam deflection and a simple, cost-effective method (integration method) to evaluate the amount of deflection and the slope at the free end of a beam. The purpose of this paper is to examine, both analytically and experimentally, the fundamentals associated with four beams made from the following materials: copper, steel, bronze, and aluminum. The analytical results from this experiment were compared with SolidWorks simulation data. SolidWorks uses the Finite Element Analysis method to determine the deflection along a beam. All characteristics of the experiment were considered in the simulation, such as gravity, length, width, thickness, and material properties. Upon successful completion of this exercise, participants understood the concept of elastic beam deflection and evaluated the deflection of a beam under different vertical loads. This exercise demonstrated the experimental values and published values match within 95%.

ENGINEERING

Thermal Conductivity of Solids

Jacob Carter, Justin Christensen, Ali S Siahpush

Southern Utah University

This paper discusses the fundamentals of conduction heat transfer and gives greater insight into an experiment to measure the thermal conductivity of solids. Conduction heat transfer occurs when energy transfers from highly energized particles to less energetic particles through a solid material. A simple, inexpensive system can experimentally evaluate the thermal conduction of a solid body. The French mathematician Jean-Baptiste Joseph Fourier derived an equation for steady-state, one-dimensional heat transfer through a plane wall, which became known as Fourier Law of Heat Conduction. This experiment uses the Fourier conduction equation to determine the thermal conductivity of a material, which is the ability of a material to conduct heat. In engineering applications, it is essential to know how a material will handle heating and cooling. An expanded knowledge of thermal conductivity will make the heating and cooling of things like homes and electronics more efficient.

ENGINEERING

Identification of Long-Term Trends In Nitric Oxide Airglow Emissions

Fon Brown

Weber State University

Data from the NASA SABER (Sounding of the Atmosphere using Broadband Emissions Radiometry)–TIMED (Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics) program has been collected for over 16 years. These data have been used extensively to study atmospheric chemistry and to improve atmospheric models. However, we propose to study the data to identify any long-term trends and/or unexpected correlations between data channels, particularly relating to nitric oxide because of its role in radiating energy from the upper atmosphere. This work will be performed primarily by students as career training experiences but will be supervised by both faculty and by members of the TIMED/SABER science team.

ENGINEERING

Airglow Measurements from SABER/TIMED Satellite

Gene Ware, Brian Simons and Doran Baker

Utah State University

Emission data as provided by LaRC, GATS, Inc., and Hampton University from the SABER (Sounding of the Atmosphere using Broadband Emissions Radiometry)–TIMED (Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics) instrument on the SABER Satellite will be validated and analyzed. Students will participate for career training experiences. Professional reports, presentations and papers will be generated. Validations and analysis will be made of the hydroxyl and molecular oxygen radiations using global and temporal correlations among each species and with observations of atmospheric buoyancy (internal gravity) waves. Particular attention will be paid to the dynamics of altitude profiles of volume emission rates in the mesosphere. Participation and reporting will be accomplished at the annual SABER Science Team meetings. Recent attention in the validation and analysis has addressed the appearance of multi-peak and bifurcation features in the profiles of limb emissions, and the derived volume emission rates. These profiles have been analyzed meticulously

for the two SABER channels dedicated to infrared hydroxyl airglow emissions. Correlations have been made with the one SABER channel which measures infrared atmospheric molecular oxygen airglow. The purpose is to establish the cause or causes of observed anomalies in the observed altitude airglow profiles from SABER/TIMED.

ENGINEERING

The Diathermometer and the Thermal Conductivity of Air

Casey Cooper, Christian Hamilton, Ali Siahpush

Southern Utah University

Thermal conductivity is a measurement of the ability of a material to conduct heat. The thermal conductivity can easily be measured for solid materials. However, it is much more difficult to measure the thermal conductivity of gases. This is due to convection heat transfer in gases making up the majority of how heat is transferred. In 1860, the thermal conductivity of air was thought to be too difficult to measure and nearly impossible to calculate. In the mid-1800s, Josef Stefan set out to build a device capable of measuring the thermal conductivity of ideal gases (including air). Around this era, there have been attempts to measure the thermal properties of gases with minimal success. The problem was finding a way to change the temperature of ideal gases without causing natural convection currents. This issue was solved when Josef Stefan developed the diathermometer. The goal of this experiment is to build a diathermometer and to use it to measure and predict the thermal conductivity of air.

ENGINEERING

Heat Transfer of a Phase-Change Material Thermal Energy System

Daniel Ulrich, Harley Glad, Ben Thrift, Ali Siahpush

Southern Utah University

Interest is growing in the utilization of passive thermal energy stored or released during the phase change of a substance. A variety of applications exist for the use of latent heat energy such as building

HVAC systems, electronics cooling, and passive heating and cooling of instruments in satellites. More than 40 years of work has been conducted in this field; however, there are still many possibilities for undergraduate engineering research to lead to new advancements. The objective of this project is to design and construct a test system to be used for experimentation and research in the thermal behavior of phase change materials. The system will consist of a vertical test cylinder that will be heated and cooled inwardly by using copper tubing wrapped in a counterflow arrangement around the outside of the test vessel. The copper tubing will be connected to a constant temperature bath that can provide fluid to heat or cool the copper tank in the range of -20°C to 100°C . Progress of the phase change will be monitored using more than 100 thermocouples. Once the test system is complete, water will be utilized as the phase-change material to validate the test system. Future work will consist of testing 99% pure eicosane ($\text{C}_{20}\text{H}_{42}$), investigating the use of porous copper foam in conjunction with eicosane to improve heat transfer performance, and measuring the thermal conductivity of the substance. Future users of the test system will be able to gain a better understanding of how this phase-change energy is stored and released in different materials.

ENGINEERING

Measuring Solar Flux and Absorptivity

Logan Evans, David Armijo, Ali Siahpush

Southern Utah University

The goal of this research was to determine the Solar Irradiance in Cedar City, Utah, and the absorptivity of an aluminum plate. This task was performed by first measuring the change in temperature with respect to time for an $8'' \times 10'' \times 1/8''$ aluminum plate. Matlab and Microsoft Excel software was utilized to analyze the data collected and determine the solar irradiance and absorptivity of aluminum 6061-T6. Solar irradiance measurements were compared with the solar irradiance measured by the Utah Red Hills Renewable Park solar plant in Parowan, Utah, at the same time and date. The absorptivity of the aluminum plate, determined from the measurements taken, was compared with published values. The solar irradiance measured was determined to have a discrepancy of 16.9% and absorptivity of an unpolished aluminum face was determined to have an approximate error of 5.1%. Uncertainty and error analysis were performed and, using these results, it has been determined that the

methods used to measure solar irradiance and absorptivity, while fairly simple and accurate, can be improved to reduce the discrepancies with published data.

EXERCISE SCIENCE & OUTDOOR EDUCATION

Unique Rituals, Pre-Performance Routines and Superstitious Behavior Used by Elite Senior Athletes

M. Vinson Miner, T. Cole Parkinson

Utah Valley University

Qualitative research methods were employed to analyze and gain insight into how elite senior athletes experience or engage in, unique rituals, pre-performance routines, and superstitious behavior. The investigation and information calculated will assist in providing better understanding of how these personal elements are exhibited by elite senior athletes, participating in a range of athletic events. A nine-point survey/questionnaire was designed and personally administered to illuminate the variety of unique characteristics and commonalities associated with this fascinating behavior. A mixture of questioning techniques were employed including a likert scale, yes/no responses, and open-ended questions. In conclusion, a majority of the responses indicated that both before and during athletic competition such rituals, routines, and superstitious behaviors were practiced.

EXERCISE SCIENCE & OUTDOOR EDUCATION

Does Individual Exercise Intervention Lead to Long-Term Behavior and Quality-of-Life Change?

L. Nathan Thomas, Joli Johansen

Salt Lake Community College

The Salt Lake Community College received permission to run a pilot exercise and lifestyle intervention program for faculty and staff. The pilot lasted 14 weeks and entailed individualized exercise programming and at least one visit per week for 14 weeks. The pilot included 79 participants, 60 female and 19 male, average age of 48. I will review the results pre/post treatment and provide data after 2 years for behavior and current patterns of exercise.

EXERCISE SCIENCE & OUTDOOR EDUCATION

Sex Difference in Concussions. Female Athletes May Show Increased Symptoms

Chase Junge

Brigham Young University

In accordance with the literature examined, it is believed that adolescent and young adult female athletes experience more severe outcomes after suffering a sports-related concussion. Women in several studies were found to experience a greater severity of symptoms, especially at the initial clinical visit. In addition to more severe symptoms, females reported experiencing a higher number of symptoms, including unique symptoms to the female sex such as an irregular menstrual cycle. Evidence was found by several groups suggesting that females have a significantly longer time to full concussion recovery than do males. The increased recovery time and symptoms may also be connected to a more significant decline in neurocognitive function seen in female athletes, as compared with males, after experiencing a concussion. Several of the focuses of the study gave unified results though more testing is needed before firm conclusions are drawn. Additional research is recommended in the area of understanding the underlying physiological basis for sex differences in sports-related concussions.

EXERCISE SCIENCE & OUTDOOR EDUCATION

Gender Differences in the Role of Acculturation, Self-Regulation, and Self-Esteem in Alcohol Consumption among Asian American Adults

Yan Huang

Weber State University

This study uses multigroup structural equation modeling procedures to examine gender differences in the role of acculturation, self-regulation, and self-esteem in alcohol consumption among Asian American adults. Methods: Data were collected using online survey. A total of 3,493 surveyed Asian Americans aged 21 years or older were invited to participate. 891 Asian American adults who had consumed at least one alcoholic drink in the past 30 days participated in the survey (response rate: 25.5%). Multigroup structural equation procedures were used to

examine the role of acculturation, self-regulation, and self-esteem in alcohol consumption. Results: For men, self-regulation positively predicted alcohol consumption ($\hat{I}^2 = .49$, $p < .001$), but for women, self-regulation did not significantly predict alcohol consumption ($\hat{I}^2 = .02$, $p = .835$). In the male sample, acculturation negatively predicted alcohol consumption ($\hat{I}^2 = .54$, $p < .001$), but in the female sample, acculturation positively predicted alcohol consumption ($\hat{I}^2 = .31$, $p < .001$). Self-esteem positively predicted alcohol consumption in men ($\hat{I}^2 = .67$, $p < .001$), but it negatively predicted alcohol consumption in women ($\hat{I}^2 = .13$, $p < .001$). Conclusion: Relationships between self-regulation, self-esteem, acculturation, and alcohol consumption in Asian Americans differ by gender. The current analysis would be enhanced by a longitudinal design able to strengthen causal explanations. Future research should also take into account immigrants' generation.

LETTERS—FOREIGN LANGUAGE, HUMANITIES, PHILOSOPHY

Two Wrongs Don't Make a Right: Monumental Foolishness in Southern Utah

Kevin Holdsworth and Jennifer Sorensen

Snow College and Southern Utah University

Professors Holdsworth and Sorensen will examine and analyze the rhetoric, justification, and process for the establishment of Grand Staircase Escalante National Monument by President Clinton and Bears Ears National Monument by President Obama, as well as the subsequent reduction and dismemberment of the monuments by President Trump. Specifically, the nature and quality of claims will be evaluated for rhetorical and factual basis. The debate over the future of the monuments invites scrutiny since issues related to the nature and purpose of governmental power, the best uses of public land, and what comprises good faith and due diligence in federal agencies are central to the examination of this topic. Also relevant is the participation of Native-Americans in the Bears Ears establishment process. Educators and activists, Holdsworth and Sorensen have been involved in public lands issues in the West for over 30 years.

LETTERS—FOREIGN LANGUAGE, HUMANITIES, PHILOSOPHY

The Impact of the Policies of the U.S. Presidents George W. Bush, Barack Obama, and Donald Trump on the Cuban Populace

Greg Briscoe

Utah Valley University

With the stroke of a pen, President Donald Trump's rollback of policy changes in U.S. relations with Cuba forced the citizens of Cuba to face a new reality dramatically different from the thaw that had been initiated by President Trump's predecessor, Barack Obama, and Raul Castro, the Cuban president. The reversal of course instituted by President Trump underscores the pivotal role American presidents can have on the daily reality of the 11 million residents of Cuba. President Trump's action changes the direction of U.S./Cuban relations from one of rapprochement to one where the Straits of Florida seem to constitute a newly restored iron curtain. This study examines the role of the U.S. president in U.S./Cuban relations by comparing the actions of the current occupant of the U.S. White House with those of his two immediate predecessors, Barack Obama and George W. Bush. The *modus operandi* of all three will be discussed vis-à-vis the interests of the Cuban state, the effect on the Cuban populace, and popular opinion on U.S./Cuba relations in the United States.

LETTERS—FOREIGN LANGUAGE, HUMANITIES, PHILOSOPHY

Translation of Culture-Loaded Tourist Attractions from an Intercultural Communication Perspective

Tingting Gu

Southern Utah University

Translating one language into another one is a process of intercultural communication. A good translation can not only reduce misunderstanding of a foreign culture, but can also help people appreciate the uniqueness of that culture. In China, names of tourist attractions are usually translated into English to tell foreign tourists the unique Chinese culture embedded in those names. However, the data I

have collected through structured questionnaire in China show that even translations given by professional Chinese translators are not accepted well by foreign tourists. That means the intercultural communication is not achieved through those “professional” translations. If we want to improve Chinese–English translations of tourist attractions, we can refer to intercultural communication theory, which can help us better understand the miscommunications in translation and identify solutions to provide better translation. This project explores how intercultural communication theory can guide translators in producing better translations, and improve communication among different cultures.

LETTERS—FOREIGN LANGUAGE, HUMANITIES, PHILOSOPHY

The Art of Letter Writing: A Reappraisal

Aymee DeLaPaz

Dixie State University

For over two millennia, the art of letter writing has been the primary link between cultures and nations worldwide. Formerly regarded as the fundamental source for education, this art has inspired the lives of numerous influential figures throughout history. Icons such as Aristotle, Leonardo da Vinci, William Shakespeare, Flannery O’Connor, Mahatma Gandhi, and Martin Luther King Jr. have altered the course of humanity drastically through their letters. Records show that this form of communication has not only been a means of conversing but also the basis for a revolution promoting self-expression, individual reasoning, amity, and equality. In recent times, the epistolary mode faces obsolescence as a result of technological advances and societal transition. As the years have progressed, the basic knowledge associated with letter writing has diminished. Penmanship, grammar, and the ability to convey one’s thoughts and ideas in written prose have likewise declined, with children, in particular, experiencing the most serious effects. And now society faces the possibility that our current generation will be the first to leave a record of itself that is electronic or digital rather than paperbound. For the sake of preserving verbal artifacts of our current and future generations and preserving a cultural art that has encouraged self-expression, reflection, and rhetorical thinking throughout time, the art of letter writing must be revived. In this presentation, using examples and arguments drawn from activists, scholars, and teachers, I address with great specificity reasons why the

letter still matters and what we can do to preserve and foster this essential literary form.

LETTERS—FOREIGN LANGUAGE, HUMANITIES, PHILOSOPHY

The Critical Vocabulary for Narration in Colloquial Arabic: A Corpus Study

Seth McCombie

Brigham Young University

For L2 students, the ability to narrate a story and understand an interlocutor's stories is critical to advanced-level speech on the American Council on the Teaching of Foreign Languages (ACTFL) scale and to making meaningful connections with native speakers. This paper investigates the relationship between an L2 student's Arabic vocabulary size and the percent of known words in Jordanian colloquial narratives. I attempt to answer two questions. First, using a small corpus (200,000 words) of personal stories told in colloquial, Jordanian Arabic, I investigate what percent of these stories a student should be able to read after studying parts one and two of the popular Arabic textbook series, *Al-Kitaab*, assuming mastery of the textbooks' vocabulary lists. Second, I use computational methods to generate a frequency list and discover which words and N-grams are most critical for third-year students to increase their comprehension of personal narratives. The texts in this corpus come from two sources. I first collected text from the Facebook page, "Naas Amman," a Jordanian version of "Humans of New York," which posts transcripts of personal interviews conducted on the streets of Amman, Jordan. I also included the transcripts of personal stories told at Brigham Young University by 3 native Arabic speakers.

LETTERS—LANGUAGE AND LITERATURE

Weird Is Good: Poetry, Evolution, and Architecture

Rob Carney

Utah Valley University

Because I'm a poet, I've been asked at times to explain what makes poetry distinct from prose, or to give an answer to the question, "What

is the purpose of poetry?" I do have answers. And I will reveal them to those who ask for them. But I'm more interested in exploring questions than providing answers. For example: how is a moose like Frank O'Hara? And why is Faulkner like stalagmites? And have you ever thought poems are like coffee shops, or gone to work as a snow-globe designer? And what does lynx music sound like? My point is that the questions we ask about poetry need to evolve to accommodate any given poem as a strange and living construction of language.

LETTERS—LANGUAGE AND LITERATURE

From Rebellion to Commodification: Jazz as a Colonizing Force in Jean Rhys's "Let Them Call it Jazz" and Philip Larkin's "For Sidney Bechet"

Randy Jasmine

Dixie State University

In Jean Rhys's short story, "Let Them Call it Jazz," the main character, Selina, experiences various forms of robbery while living in London. Perhaps the most egregious of these crimes against her is the appropriation of a song she sings that she first heard while in prison. This song is stolen from Selina when someone hears her sing it at a party. The tune is "jazzed up" and eventually becomes a mainstream hit. The poet Philip Larkin was a well-known aficionado of jazz, and this passion spilled out in his literary career. Larkin and his colleagues at Oxford in the 1940s saw jazz as a way to rebel against the stuffy establishment of dons and scholars at that venerable institution. In the poem named after one of his favorite jazz artists, "For Sidney Bechet," published in 1954, Larkin admiringly proclaims, "On me your voice falls and they say love should, / ... My Crescent City / Is where your speech alone is understood" (13-15). Larkin's reverie is clear and his admiration touches on the euphoric as he ascribes to jazz a power that goes even beyond his own power as a poet. There is another way, however, to read Larkin's words in this poem: Larkin sets himself up as the ultimate arbiter of both value and meaning in relation to Bechet's music. His proclamations represent the same type of intercession and white male hegemonic appropriation that Rhys so strenuously objects to in her story. In the last decades of his life, Larkin wrote far more jazz criticism than he did poetry, and he began to use jazz to reinforce established class and racial distinctions rather than as a weapon to defy such inequities. Much like the unnamed man in Rhys's story who appropriates Selina's song and

attempts to silence her West Indian voice, Larkin in his later life, as a recognized authority on jazz, pronounced sentence on a wide variety of jazz artists, many of whom were positioned on the margins of society. Selina ultimately rejects the annexation of her song and at the very end of the story, choosing to maintain her independence, she declares: "So let them call it jazz, I think, and let them play it wrong. That won't make no difference to the song I heard." Music for her remains the means of defiance that it never really was for Larkin.

LETTERS—LANGUAGE AND LITERATURE

The Territory We Have Left Behind: J. M. Coetzee's *Elizabeth Costello* and Neo-Materialism

Sean Jenkins

Weber State University

J. M. Coetzee's postmodern novel *Elizabeth Costello* should be read against the grain of its polemic to appreciate it as a complete work of literary art. Its persuasive powers, insofar as they exist, are realized as such in their stylistic execution. The novel can be "unstitched," its controversy cut apart from its artistry, but I argue against such a fragmented reading or interpretation or analysis of the novel. The power of the novel's polemic is, in large part, a function of its craftsmanship, and unstitching it, as Neo-Materialists are wont to do, destroys its wholeness, artistry, and integrity.

LETTERS—LANGUAGE AND LITERATURE

Queequeg: Cannibal and Savior of the Pequod World

Megan Naihe

Weber State University

In Herman Melville's *Moby Dick*, Queequeg combines the characteristics often associated with so-called "savage" cultures with the redemptive qualities associated with Christ. He is a South Seas cannibal from a fictional island, and yet he is also the savior of the Pequod world, as his own symbol of death, his coffin, literally saves Ishmael. Through my presentation, I argue that Queequeg's character exposes hypocrisies of religion and colonization. He is a cannibal; however, 19th-century

America and other “civilized” countries behaved like cannibals: consuming primitive places and people by destroying and devouring their resources and cultures. Thus, his character offers readers an alternative, superior solution to colonization and capitalism. Rather than conquering and converting people, Queequeg teaches others—especially Ishmael—redemptive attributes of understanding, acceptance, and respect.

LETTERS—LANGUAGE AND LITERATURE

Mark Twain’s Geographic Imagination in *Life on the Mississippi*

Todd Goddard

Utah Valley University

Twain’s relationship to and understanding of place is characterized by robust sense of nostalgic identification and attachment. Yet Twain demonstrates in *Life on the Mississippi* that place is inherently open and always in process. For Twain, place is more event than static object, more verb than noun. Rather than fixed and unchanging, it is an articulated moment in an ongoing and neverending process of change (both social and “natural”) and a constant reordering of a constellation of social relations. Through an investigation of *Life on the Mississippi*, this paper explores Twain’s articulation of a nostalgic and portable sense of place that ultimately resists what he sees as the inherent instability and inevitable dissolution of place. In doing so, Twain anticipates present-day geographers like Doreen Massey by recognizing the radical openness and constant changeability of place. Indeed, by detailing the physical and cultural history of the Mississippi River, and through his elaborate description of his education as a riverboat pilot, Twain suggests that place itself can be preserved only in memory and only by those properly trained to read it. In addition, the paper will explore recent critical debates on the nature of space and place, the relationship between temporality and spatiality, human interactions with landscape and environment, as well as the tensions between the local and the global.

PHYSICAL SCIENCES

a-Si as a Protective Layer to Block the Oxidization of Al Mirrors

David D. Allred, R. Steven Turley

UCLA

Arguably, the best chance to produce an infrared-optical-ultraviolet-extreme ultraviolet (EUV) mirror for a future space observatory is a EUV multilayer mirror coated by a very thin bare aluminum layer. However, using a bare Al layer presents challenges that first must be overcome. Al oxidizes rapidly when contact with the atmosphere occurs. The customary solution is to cover the mirror with a protective evaporated fluoride layer. Unfortunately, these are opaque under ~ 110 nm whereas Al is reflective down to 85 nm and could be used as a mirror without a barrier. Once the mirror is in space, where there is no oxygen, Al would no longer need a barrier layer. Fluorides cannot be removed once they are deposited without damaging the mirror. a-Si could be used as a protective layer that is potentially removable. A dry chemical process that would use the Al layer as an etch-stopping barrier could be used to remove the a-Si protective layer. It is hypothesized that this could be done without roughening the aluminum, but such a process has not been researched for this purpose. We will report on the first step of evaluating a-Si as a barrier, that is, its properties as a protective layer to block aluminum oxidation.

PHYSICAL SCIENCES

Using Exoplanet Transits to Calibrate the Great Basin Observatory

Rhett Zollinger

Southern Utah University

Southern Utah University is one of four university partners who manage and operate the new Great Basin Observatory (GBO). The GBO became operational in August 2016. Because the telescope is still new, some of its capabilities are still untested. To determine the telescope limits for exoplanet transit detection, we have started taking photometric measurements of transiting systems. We then verify that the results from our photometric data are consistent with expected values. So far, we have

successfully analyzed several transits and are still in the process of determining the lower limit for transit depth detection. Once our work is finished, we will have a better understanding of the GBO capabilities, which will benefit future SUU students and other GBO university partners. In our presentation, we will explain our method for exoplanet transit observation and discuss our results.

PHYSICAL SCIENCES

CCD Measurements of AB and AC Components of WDS 20420+2452

Alan Nelson, Kevin Andrews, Ethan Brown, and Bryan May
Southern Utah University

Measurements of position angles and separation are obtained from CCD images and recorded for the triple star system WDS 20420+2452 with components POU4886AB and POU4887AC. Our measurements suggest that component B is not gravitationally bound to the primary component. No orbital trend is observed for POU4887AC, but further observations may indicate an orbital trend.

PHYSICAL SCIENCES

Optical constants and oxidation of niobium thin films

David D. Allred
Brigham Young University

Computer models show that ultrathin niobium films may be a useful part of a near-normal incidence, extreme ultraviolet multilayer reflector for the range of 25 to 35 nm. Our calculations indicate that the highest reflectance in such multilayers will come with the niobium layer on top. Therefore, it is important to know how fast the niobium films oxidizes in dry air, since chemical and structural changes in the top layer will drastically change the optical performance of the multilayer. We report on the kinetics of the room-temperature oxidation of sputter-deposited several niobium films (thicknesses ranging from 5 to 15 nm) on samples of cleaved silicon nitride-coated (100-orientation) silicon wafers. Whereas previous investigators of Nb thin films analyzed their data in terms of the Cabrera-Mott model, which shows the thickness of the oxide

film increasing logarithmically with time, we observed linear or parabolic oxidation in our ultrathin films. We will discuss the use of variable-angle spectroscopic ellipsometry as a quick, relatively easy-to-use tool to study the oxidation of thin-film Nb layers. We also report the optical constants of our ultrathin Nb films.

PHYSICAL SCIENCES

Tidal Disruption Events Around Massive Black Holes

Payton Christensen, Kyle Christiansen, and Brandon Wiggins

Southern Utah University

We have a supermassive black hole in the center of our galaxy (Sagittarius A). A stellar (or average-sized) black hole is created when, in essence, a star collapses in on itself. Although stellar black holes may be 10s of solar masses in size, supermassive black holes tend to weigh millions or tens of billions of suns. The growth of massive black holes depends on the character of their accretion disks. We study the formation of accretion disks by the phenomena of tidal disruption, which gives insight into supermassive black hole formation itself. We tested several specific scenarios involving the course of a star in the vicinity of a black hole. Using smoothed particle hydrodynamics, we modeled the process of tidal disruption on the star in its trajectory, spaghettification, and consequent obliteration. We discuss implications of our results for how massive black holes may have grown through cosmic time.

PHYSICAL SCIENCES

What a Genetic Algorithm-based, Optical-design Program Teaches Us about Dual-function (Extreme Ultraviolet + Broadband Ultraviolet-optical-infrared) Multilayer Mirrors

R. Steven Turley

Brigham Young University

NASA has identified as a key technology requirement, deemed an essential goal for future flagship missions such as LUVOIR (Large, ultraviolet-optical-IR surveyor), improving the operating efficiency and environmental stability of standard aluminum (Al) mirrors at

wavelengths shorter than the operating cutoff of Hubble Space Telescope (HST) at 115 nm. Only Al mirrors can achieve high reflectance far into the ultraviolet (UV), as low as 85 nm, aluminum plasma edge. Unfortunately, Al oxidizes rapidly upon air exposure, diminishing the reflectance of bare Al mirrors below 200 nm. While a minor problem on Earth—the atmosphere blocks radiation below this wavelength—mirrors used in space could use the whole range of Al's high reflectance, if a bare, or nearly bare, Al mirror could be deployed. In addition to providing reflection over the important Lyman UV (93–122 nm), bare Al mirrors could make possible extreme ultraviolet (XUV) reflectance as well. This is because below its plasma edge, Al thin films are partially transparent down to Al L edge at 17 nm. This is the focus of this report. If an appropriate EUV multilayer underlies the Al, its reflectance can give the mirror high UV reflectance at the designed wavelength. We have designed multilayers for 25.6 nm that correspond to the 3P to ground-state transition in singly ionized helium (He II). Helium is the second most common element in the universe, and its emissions can help characterize energetic astrophysical sources. This is a challenging portion of the spectrum to obtain high-performance multilayers, because most materials are quite absorbing. We have used a genetic algorithm program to find multilayer combinations with high reflectance. We will discuss what the multilayer calculations teach about obtaining high reflectance in the longer wavelength portions of XUV.

PHYSICAL SCIENCES

The Effects of Surface Roughness on Reflectance

Michael Greenburg

Brigham Young University

My research involves determining the effect on reflectivity of surface roughness that is similar in scale to the wavelength of incident light. The influence of surface roughness is fairly well understood in the cases that it is much smaller or larger than the wavelength of light being reflected, but otherwise simplifying approximations break down. One must solve a boundary integral problem to determine reflectance as a function of angle; discretizing and turning this problem into a matrix-vector equation allows one to write and use a computer program to find the solution. I have inherited a program that does so in two dimensions (using a slice of a full 3-D surface, with only x and z coordinates), and retrofitted it to allow massive parallelism. I am currently building a program that does

so in three dimensions, which will allow me to confirm that the results of the 2-D program are consistent with what we expect in three-dimensional space. Because the 2-D program is vastly more memory-efficient, confirming that it accurately represents reality will allow us to confidently perform massive computations without the costs of finding a full three-dimensional solution. Large simulations are important because small simulations imply small surfaces, and reflective performance decreases as surface size decreases. It is therefore challenging to isolate the decrease in reflectance that is due to roughness with small simulations. Huge computations will allow the effect of small surface size to be trivialized, giving a much-improved model of the effects of wavelength-sized roughness. I will report on the implications of consistency between the programs, progress on the 3-D program and on preliminary results from the 2-D program.

PHYSICAL SCIENCES

Helping Students Overcome Difficulties in Math With Physics

Jacob Siebach

Brigham Young University

Having taught middle school, privately tutored individuals and worked with high school and college students, I have seen (and experienced myself!) challenges in connecting mathematical concepts to real situations. I will share the experiences that I have had in discovering the “pain points” of the students. I would like to develop a curriculum that spans several semesters. Instead of teaching first-semester Physics and Calculus separately, I would like to take two semesters to teach Trigonometry and Calculus as a part of the Physics class. Since Newton invented the Calculus to explain Physics concepts, it is most easy to present a physical problem to the student and then teach them the mathematical tool used to solve it. This is akin to teaching someone how to build a birdhouse, which involves learning the use of a measuring tape, saw, and hammer as part of the process. Similarly, I believe that by teaching half of Physics I and Calculus I in one class and then teaching the second half of both in the following semester, students will see the physical concepts for which the tools were designed, and they will begin to intuitively understand when to use which tool to solve the problem. I would like to begin a discussion on the challenges that will be involved

in assembling such a series of classes, along with the potential advantages.

PHYSICAL SCIENCES

Sun Fire on Earth: The Hydrodynamics of Kiloton Explosions

Brandon Wiggins

Southern Utah University

Nuclear weapons and proliferation are becoming more of an issue in today's world. As this continues to become an increasing threat, the effects of a nuclear blast need to be better understood. In our research, we will be using FLASH, an authoring software, to better understand the magnitude of the shock wave and the spread of its effects. To do this we will be testing different parameters and observing how they affect the hydrodynamics of a nuclear shock wave. To show the results of our observations, we will be creating pictures, graphs, three-dimensional images, short videos, and calculations. These will be generated using FLASH and a supercomputer. This research will allow a better understanding of nuclear blasts, their effects and the parameters that may affect them.

PHYSICAL SCIENCES

The Mathematics of Mario Party 10

Andrew Misseldine

Southern Utah University

The Mario Party video game franchise by Nintendo has offered a fun, wholesome party game experience for millions of happy gamers since 1998. The newest installment of the series, Mario Party 10 for the Wii U, continues in this tradition. These video games play like a board game but with regular mini-games where players battle for coins and hearts. While players can best these mini-games by strategy, skill, timing, and massive button-mashing, victory in these mini-games and the overall board game often comes down to luck. From dice rolls to card drawing and other games of chance in between, this talk will analyze effective

Mario Party 10 strategies based upon the mathematics of probability and group theory.

PHYSICAL SCIENCES

How Rational Functions Shape the World—Through Phase Transitions among Physical States

Chin-yah Yeh

Salt Lake Community College

Rational functions are fundamental in manifesting phase transitions and critical phenomena, which are crucial in the onset and evolution of the universe. Every rational function $R(x) = P(x)/Q(x)$ can be decomposed into two parts: a polynomial and a sum of poles, where each pole is characterized by a real or imaginary number. By carrying out analogy and extending the argument to other metric spaces, we test on rescaling the complex plane and try to elucidate phase transitions in the physical world.

PHYSICAL SCIENCES

Classifying the Schur Rings Over the Integers

Andrew Misseldine

Southern Utah University

Schur rings are a type of algebra that is spanned by a partition of finite groups that meets other conditions. Schur rings were originally developed by Schur and Wielandt in the first half of the 20th century to study permutation groups and have since been more widely studied. They were especially studied in the 1980s and 1990s to look at finite cyclic groups, which are finite sets that cycle through their elements equipped with an operation satisfying certain properties. Past research has provided a classification of Schur rings over finite cyclic groups. We will provide an extension of this classification to Schur rings over infinite cyclic groups. This will be accomplished by using a mapping technique involving what we call freshman exponentiation. Using this we will show that there are only two types of Schur Rings over the integers up to isomorphism. As all infinite cyclic groups are isomorphic to the integers, this will prove our claim.

PHYSICAL SCIENCES

A Neural Network for the Non-invasive Differentiation of Cancer Cells Using Near-infrared Laser Scattering Data

**Ryan Bevan, Mason Acree, Daniel Blumel, Christopher Berneau,
James Graham, Diana Turcios**

Utah Valley University

Cell nuclei are responsible for ~40% of the optical scattering that occurs in a cell. Although these nuclei are typically spherical in healthy cells, they begin to enlarge and elongate during the earliest stages of most cancers. The complex structure of these cells makes it difficult to accurately simulate optical scattering in vivo. As a result, recent efforts have involved the application of artificial intelligence to analyze scattering patterns from cells without the need to physically model the complex interactions involved. In this study, we investigated optical scattering patterns for five different cancer cell lines, which were irradiated in vitro by near-infrared diode lasers at wavelengths of 532, 635, and 850 nm. The resulting patterns were collected with a CCD beam profiler and used to train a neural network. Significant differences were observed in the appearance and spectral distributions for the various cell lines. Spherical WEHI-3 cells were used as a control and compared with MIE scattering simulations for spherical particles. Accurate quantification of these patterns could lead to the detection of cancerous cells at low concentrations in otherwise healthy tissue, thereby providing a mechanism for non-invasive cancer cell detection and earlier screening methods.

PHYSICAL SCIENCES

Silver Nanoparticle Synthesis with Microfluidic Devices

Christopher Monson, Rachel Radmall, Max Brown

Southern Utah University

Our research focuses on the synthesis of silver nanoparticles using microfluidic devices. These devices are of particular interest to us because of the controlled environment that they provide for reactions to take place. As the name suggests, the “micro” scale of this device gives us a high surface area-to-volume ratio, while the “fluidic” aspect allows

a controlled flow rate and pattern. This provides reproducible products with accuracy and precision. Our microfluidic device is created by using polydimethylsiloxane (PDMS), a polymer that is similar to glass. Using a magnesium wire, we can shape our microfluidic device to fit the needs of our experiment and then suspend it in PDMS. The magnesium wire can be dissolved once the PDMS solidifies, forming a hollow chamber in which we can perform our reaction and synthesize our silver nanoparticles. Silver nanoparticles have a wide range of applications, but the focus of our research will be to learn more about what causes inconsistency in the size of the particles. Since one of the major challenges of nanoparticle synthesis is creating a product that is uniform in size, learning how to control the synthesis process to create highly uniform nanoparticles would be beneficial. To accomplish this, we plan to gather more information about the nanoparticles using Raman spectroscopy. We will also use a ultraviolet-visible spectrometer and spectrofluorimeter to analyze the stages of nanoparticles synthesis.

PHYSICAL SCIENCES

Quantum Erasure with the Stern-Gerlach Effect

Jean-François Van Huele

Brigham Young University

Wave-particle duality is one of the most fundamental principles of quantum theory. Consequently, objects on the quantum scale can exhibit both wave properties (e.g., self-interference) and particle properties (e.g., defined path). These wave and particle properties are complementary in the sense that the more a quantum object behaves as a wave, the less it behaves as a particle, and vice versa. The degree to which a quantum object behaves as a wave or a particle can be changed by entangling one of the object observables with another observable in the system. This change can be reversed either entirely or partially by creating another entanglement. This reversal process is known as quantum erasure. The Stern-Gerlach effect has been shown to split a beam of quantum objects into multiple beams with defined spin. The result is that the object spins become entangled with their positions. We present an analytic expression for the time evolution of quantum objects experiencing this effect and visualize the interference fringes that arise in such a system with multiple Stern-Gerlach events. We note that the phenomenon of quantum erasure is evident and quantify the corresponding effect on the quantum object wave and particle properties

PHYSICAL SCIENCES

Measuring Oxygen Levels in Anoxic Environments Using a Microfluidic Device

Brian Anderson

Southern Utah University

Aquatic anoxic environments affect many aspects of the world around us. For example, fish require dissolved oxygen to live, and our pipes will corrode more easily if oxygen levels are too high. We have fabricated a microfluidic device that is sensitive enough to measure low levels of oxygen and is reusable and inexpensive. Our device consists of a block of polydimethylsiloxane with embedded wires and channels. It measures oxygen in anoxic aqueous environments using an electrochemical process analogous to that of the Clark electrode. Our design is based on the STOX electrode, which is essentially a Clark electrode inside of another Clark electrode. The STOX electrode is sensitive, and we hope our device will have similar sensitivity but will be less expensive. We have successfully fabricated a device, calibrated it, and performed field tests.

PHYSICAL SCIENCES

Spectroscopic and Quantum Chemical Investigation of Nature's Most Adaptive Photosynthetic Pigments

Clayton Staheli, Kelsey Rico

Southern Utah University

Photosynthetic organisms have realized the Sun's potential as a source of nearly unlimited energy for billions of years. They have developed the machinery to harness the Sun's energy in an all-encompassing solar cell including an efficient light-electric transducer akin to our own solar cells, but with the added benefit of a long-term storage mechanism in chemical bonds. The front-end of photosynthesis is the light-harvesting step, which all subsequent steps crucially depend on. As such, this step is generally the most efficient, with light capture and transport occurring at efficiencies routinely >90%. At the heart of this efficiency is nature's molecular design of light-harvesting proteins containing pigments that absorb the sunlight and rapidly transfer that energy among themselves and to other proteins so that it may be converted to electrical potential.

The primary pigments utilized by cryptophyte algae and cyanobacteria belong to a class of molecules called bilins, or linear tetrapyrroles, and are arguably the most chemically/structurally diverse pigment class found in nature's enabling organisms to tailor their light capture to their environment and light availability. To address the intrinsic light-harvesting properties of this special class of pigment, we take a bottom-up approach employing ultraviolet-visible, fluorescence, and infrared spectroscopic studies coupled with high-level structural calculations of the individual pyrrolic subunits that make up these tetrapyrroles, followed by di-pyrrole subunits, and finally entire bilins. This approach enables us to investigate the nature of those electronic states responsible for light absorption and to track them as the structure is built up to larger and larger units. We have found that already at the dipyrrole level the pigments begin to absorb light in the solar range with high efficiency. Furthermore, structural and chemical differences have shown a distinct impact on these properties.

PHYSICAL SCIENCES

Soil Analysis of Molybdenum Metal near Milford, Utah

Kim Weaver, Elizabeth Pierce

Southern Utah University

Because molybdenum forms a complex with many different biomolecules that are responsible for nitrogen fixation and other essential cycles, we hypothesized that areas denser in foliage would have higher concentrations of molybdenum in the soil. Our study site, just northwest of Milford, Utah, is near the outflow of an old tungsten mine. Initial surveys found variable molybdenum concentrations over an area of about six square miles, providing diverse, natural areas to take sampling from for our study. We took three samples each from 11 different areas, where the first sample was directly under a sage bush, the second was about a pace away, and the third was two paces away. We then measured the molybdenum concentration using soil digestion methods, and we are currently measuring the amount of biomatter in each sample through combustion of the soil in a muffle furnace. We demonstrate that molybdenum concentrations in soils do not particularly change over time, allowing for further study, and we are working on determining whether molybdenum concentrations are greater near sage bushes and other areas high in organic mass.

PHYSICAL SCIENCES

Reconstitution of Supported Lipid Bilayers into Lipid Vesicles

Mike Ornstead, Ruth Hunter

Southern Utah University

Lipids are an important part of cell membranes. When in water, these lipids form a model cell shape called a vesicle. When lipid vesicles come in contact with smooth glass, they form supported lipid bilayers (SLBs), which are unrolled, flattened, lipid vesicles on glass. These bilayers are important for the purification, separation, and study of cell membrane substituents. We form an SLB in a microfluidic device to study the conversion of bilayers into vesicles. As a fast-moving buffer flows over these bilayers, it disrupts the bilayer and strips portions of it from the glass. We hypothesize that these stripped lipids are then reformed into vesicles. However, we can only observe their stripping. We are building a particle analyzer to determine the number and size of the particles that are produced from stripping the bilayer. In our device, a laser shines on the solution from the stripping experiment and the scattered light is analyzed thus making a light scattering particle sizer.

PHYSICAL SCIENCES

Using the Chemical Composition of Coal Creek to Better Understand the Lack of Biodiversity

Porter Edwards, Kim Weaver

Southern Utah University

Coal Creek in Cedar City, Utah, has very low or no biodiversity present. Some of the creeks above Coal Creek have been found to have some living organisms. This sparked the question as to why the main creek does not support life. Since the fall of 2012, hundreds of samples have been analyzed to determine the concentration of total metals, dissolved metals, anions, chlorophyll, and more. The purpose of this research is identify possible explanation behind the low biomass and biodiversity of the creek. Principally, we have focused on the chemical characterization of the creek and its tributaries to better understand the processes occurring within Coal Creek. The data collected will be presented and hypotheses will be shared as to why Coal Creek cannot sustain life.

POSTER

Examining the Ideal Conditions for Crude Oil Bioremediation by Algae Species

Brady Webb, Braden Nickle, Morgan S. Abbott

Utah Valley University

Oil spills are highly volatile to aquatic ecosystems. According to the EPA, there are a variety of approaches to address oil cleanup, including controlled burning, dredging or dispersing detergent that has a higher density than water, solidifying (which helps change oil from a liquid to a solid), and finally bioremediation by microorganisms. Bioremediation is an effective way to clean up oil spills in sensitive areas such as shorelines. To accelerate bioremediation, additional chemicals such as nitrogen and phosphorus are added. We plan to examine what conditions are optimal for bioremediation. We will use three species of algae: *Anabaena oryzae*, *Chlorella kessleri*, and *Chlorella vulgaris* under different nitrogen treatments. Humidity, salinity, heat, light, and oil concentration will be constant in all treatments. Our principal variable will be the different concentrations of nitrogen. We will also be testing the efficiency of combinations of the species. For each treatment we will also measure the change in viscosity of crude oil three times a week. Measuring viscosity will help us measure oil remediation (degradation) because when algae break down hydrocarbons there is a change in viscosity. This research has a wide variety of environmental applications in different ecological environments contaminated by oil spills.

POSTER

Thigmomorphogenic Response in *Arabidopsis thaliana*

Brian Williams, Deric Searle, Brandon Peterson

Utah Valley University

The researchers attempted to induce irregular growth in *Arabidopsis thaliana* with variable speeds of vibration and verify changes in growth by measurement of growth parameters such as length, dry weight, and chromophore density to verify the thigmomorphogenetic response of this plant to mechanical stress at such frequencies. Three groups of *A. thaliana* were treated with low-, medium-, and high-intensity RPM settings to induce thigmomorphogenesis and document any differences

in robustness between groups. Statistical analysis will be performed and the results will be presented.

POSTER

Vermicomposting Spent Brewer's Grain (*Secale cereale*, *Triticum aestivum*, and *Hordium vulgare*) for Fertilizer Application on *Raphinus sativus*

Summer Roberts, Whitney Weinberg

Utah Valley University

Vermicomposting is the practice of using worms to consume organic waste and leave behind castings (worm excrement) that are enriched with nutrients and moisture. This compost can be utilized directly as castings, or liquefied into compost tea for fertilizing crops, household plants, or just general enhancement of the land. Spent brewer's grain is the leftover germinated grains used in the production of beer and other malt products. Spent grain makes up a total of 85% of the bio-waste during production. This research project involved spending malt rye, barley, and wheat mimicking the brewer's process. Four different vermicomposting bins were differentiated for these three grains and an equal portion of them. In addition, two trials for chemical fertilizer and no fertilizer were done. Two trials were done administering the different compost tea to *Raphinus sativus*; four replicates were done totaling 24 plants. The results of these experiments will be discussed. This research provides important information on the production of vermicompost for different horticultural applications, including organic growth of plants.

POSTER

Effects of Caffeine on Growth and Development of Mustard Seed

Alyssa Baccus, Michael Foster, Brandon Richards, Stephanie Vasquez

Utah Valley University

Yellow mustard seed plant, or *Brassica alba*, is used as a major spice worldwide and can also be ground into the widely popular yellow mustard. An increase in plant mass could benefit the quantity of spice

and mustard being made, increasing profits. There are many chemicals that can affect overall plant mass, but one that has not been explored in depth is the effect of different concentrations of caffeine on plant growth and mass of *B. alba*. The purpose of our experiment is determine whether caffeine can increase plant mass growth of *B. alba* (mustard seeds), which could be beneficial for commercial crop growth. During our experiment, we will use the following concentrations of caffeine solution: 0 M (control), 0.01 M, 0.001 M, and 0.0001 M. Each concentration will be applied to five separate replicate *B. alba* plants. We will monitor the *B. alba* growth over two months, watering twice weekly, and measuring the height weekly with other relevant plant health observations. At the end of the two-month period, we will measure dry mass by removing the plant from the soil, rinsing it off, and measuring. Following our experiment, we will summarize all required data and evaluate whether caffeine concentrations in the water affect the overall plant mass and development of *B. alba*.

POSTER

Targeted Mutagenesis and Repair via CRISPR/Cas9 and Homology-Directed Repair of Melanogenic Genes

Jacob Kirkpatrick, Josh Kirkpatrick, Erika Smith, Eric Domyan
Utah Valley University

Pigmentation is a phenotype that often impacts an organism's fitness through natural (e.g., camouflage) and sexual (e.g., ornamentation) selection. In mammals and many birds, pigmentation is due primarily to the amount and type of melanin produced by melanocytes. The *Tyrp1* gene codes for the tyrosinase-related protein (TYRP1) and is involved in the melanin production in melanocytes. A mutation found in the *Tyrp1* gene in pigeons causes an ash-red feather color as opposed to the black, wild-type color. Although the function of *Tyrp1* in melanin synthesis is not well understood, it is thought to be responsible for the ash-red phenotype when mutated (Domyan and Shapiro, 2014). The broad objective of our research is to study the effect of the pigeon ash-red mutation on *Tyrp1* function, through targeted mutagenesis in mouse melanocytes. We will utilize the CRISPR/Cas9 system to make a gene edit in the *Tyrp1* DNA sequence of mouse melanocytes to characterize the effects of the mutation found in pigeons. The CRISPR/Cas9 system uses the Cas9 enzyme to create cuts in the DNA at specific locations of interest designated by a guide RNA (gRNA) that matches the desired

target sequence (Cong et al, 2013). The CRISPR/Cas9 enzymes also allow for gene insertions at gRNA-directed sites. We will do this by using CRISPR to cause a homology-directed repair (HDR) of the DNA strand where we will provide a template containing the desired amino acid change (alanine to proline) to better understand its effect in pigment production. Our hypothesis is that upon successful introduction of the ash-red pigeon mutation into mouse cells, we will be able to observe the same ash-red pigment production in mouse melanocytes as is observed in ash-red pigeon feathers.

POSTER

A Study of Ringtail (*Bassariscus astutus*) Genetic Diversity in Southern Utah

Laura Allard, Laurie Mauger

Southern Utah University

Genetic diversity in populations of organisms is important information for conservationists because it can give indication about the overall health of the population and their future viability in their current habitats. Low genetic diversity can be very dangerous for populations, especially those populations with lower numbers of individuals. The lower the genetic diversity in a population, the greater the risk they face when dealing with environmental changes and introduction to pathogens. Ringtails (*Bassariscus astutus*) are small, nocturnal carnivores that are found from southern Mexico to southern Oregon, and on 3 islands in the Sea of Cortez. They are part of the raccoon family and somewhat resemble a weasel with a black and white ringed tail much like the ring-tailed lemur of Madagascar. Ringtails are considered to be mesocarnivores, with diets consisting of 50–70% meat and the rest consisting of plant matter. Many mesocarnivores are now rare and even critically endangered. This study focused on conservation genetics for the ringtail, with an emphasis in their biodiversity. Microsatellite DNA was used from the ringtail to determine population diversities of the ringtails in the Zion and Bryce National Parks and to determine how many individuals frequent these areas. The overall aim of the study is to use DNA analyses to determine the viability of the ringtail in southern Utah and possibly use this information to make further conclusions about ringtail range, ringtail relatedness, and ringtail impact in the ecosystem they reside within.

POSTER

Ant Genera Distribution at Three Peaks Recreation Area between Sunny and Shady Locations

Shelby Berryhill, Katelyn Glauser, Keli Kennerly, Justin Mickelson, Aiden Reed, Stephen Navin, Dalton Skidmore, Carrie Jo Bucklin

Southern Utah University

The purpose of this study was to find ant diversity in different environments and use the compared populations to explore biodiversity and the health of an ecosystem. We analyzed the diversity of ants in the Three Peaks area based on distribution between sunny and shady areas. We hypothesized that there would be a difference between the distribution of ants in sunny and shady areas, and we expected sunny areas to have the most ants. We collected and identified ants at multiple locations in each site. We then calculated the chi-square between locations to determine if there was a pattern in our data, and then completed a t-test. We found a significant difference between sunny and shady ($p=0.05$, $X^2= 17.499$).

POSTER

Occurrence and Abundance of Milkweed (*Asclepias L.*) in Irrigation Channels Adjacent to Roadsides and Cropland

Ashley Ardon, Daniela Gomez, Denise Rodriguez, Hayley Moyes, Selena Oltehua, Melissa Robles, Cody Zesiger

Roy Junior High School (consulting with Weber State University)

It has been well documented that urbanization, expansion of croplands, and widespread usage of glyphosate is responsible for a significant reduction in milkweed (*Asclepias sp.*) and monarch butterfly (*Danaus plexippus plexippus*) populations. What has not been studied is whether some land practices may benefit milkweed and likewise monarchs. In the Intermountain West, roadsides next to cropland are often used for irrigation and contain many non-cultivated plants. In 2017, counts of milkweed basal stems were performed at randomly selected roadside channels adjacent to cropland ($n=10$). Randomly selected stems were collected from 3 of the sites for analysis. The stems dried for 60 days

indoors above a radiator. Desiccated stems were manually defoliated. The leaves were counted, crushed, and weighed individually if the whole leaf was undamaged. Leaves were weighed collectively if they were damaged during drying. Milkweed occurred in 10 of 10 randomly selected sites in Weber County. The parameters for site selection were that the site must be an irrigation channel and be adjacent to roadsides and/or cropland. The mean of milkweed basal stems per m² was determined to be $0.15/\text{m}^2 \pm 0.103/\text{m}^2$ (95% confidence limits). The mean of leaves per stem (n=10) was 17.3 ± 5.6 (95% confidence limits). The total dry matter per leaf (n=82) was $0.74 \text{ g} \pm 0.114 \text{ g}$ (95% confidence limits). These results indicate a generous quantity of milkweed in irrigation channels adjacent to roadsides and croplands. Whether monarchs utilize these spaces as breeding grounds has yet to be determined. However, if it is established that these sites are selected by monarchs as breeding grounds, similar sites to these may be of significant importance to the management of the western monarch population in rural areas.

POSTER

***Wolbachia* Infection Rates in Southern Utah Ants**

Logan Tuttle, Laurie Mauger, Carrie Bucklin, Sam Wells

Southern Utah University

The study of endosymbionts has become an important field of study because it allows us to better understand the effects these bacteria have on their eukaryotic hosts. Once such endosymbiont, bacteria from the genus *Wolbachia*, has piqued the interest of scientists when it comes to the role they play in arthropod populations. *Wolbachia* are a group of maternally inherited, intracellular bacteria that infect many species of arthropods and some other invertebrates. They are exclusively found in the reproductive tissues and can cause reproductive alterations in infected hosts. These alterations can potentially have many effects on arthropod population structure. Understanding the function of *Wolbachia* provides important knowledge about reproductive trends, population structure, and genetic diversity. Studying the effects of *Wolbachia* on reproduction can provide information for population manipulation, pest control, and disease prevention. Various studies have been performed around the world to determine infections rates, but little is published about the presence of *Wolbachia* in Southern Utah and the surrounding region. Therefore, this research is designed to determine

Wolbachia infection rates in Southern Utah ants and to determine if infection rates are similar to other locations that have been studied. Ants will be collected and characterized down to the genus level. Individuals will be isolated, and diagnostic PCR will be used to verify the presence of *Wolbachia* in extracted DNA using *Wolbachia*-specific primers at the *wsp* gene. Infection rates will then be determined and compared among ant genera and locations.

POSTER

Mutation in the Rock Pigeon Genome Causes Unique Pigmentation by Altering Gene Expression

Jeremy Hardy, Jordan Daniels, Eric Domyan

Utah Valley University

The domesticated rock pigeon has been the subject of selective breeding for over a hundred years and so displays an immense variety of phenotypes. This variety provides opportunities to further understand the genetic basis of phenotypic evolution. Pigmentation of pigeon feathers is controlled by multiple alleles at different loci, which influences the type and amount of melanin deposited in the feathers. A specific phenotype, known as “recessive red,” consists of distinctly red plumage and is caused by a mutation that greatly reduces the expression of the gene *Sox10* (*Sry-box 10*) (Domyan et al. 2014). This gene encodes a transcription factor known to play a key role in melanocyte maturation and proliferation (Harris et al. 2010). *SOX10* likely regulates the transcription of multiple downstream genes, but the identities of these genes are largely unknown. To identify which genes are downstream targets of *SOX10*, we compared the transcriptomes of regenerating feathers from wild-type and recessive red birds to identify genes that had different expression levels between the two groups. We identified 46 genes that are expressed at different levels between wild-type and recessive red birds, and thus are potential targets of *SOX10*. While several of the target genes have known roles in pigmentation, the role that many of the targets play in pigmentation has not been studied, making them interesting candidates for further investigation. To validate the transcriptome data, we are conducting qRT-PCR to see if an independent approach yields similar results. Through analysis of the recessive red phenotype, we can better understand the dramatic effect that mutations play in the evolution of new phenotypes.

POSTER

Synergistic Activity of Clove Oil and Amphotericin B against *Absidia corymbifera* Biofilm

Jedediah Orullian, Hutch Rhees, Caeleb Harris, and Olga Kopp
Utah Valley University

This study investigates the synergistic antifungal activity of amphotericin B (Amp B) and *Eugenia caryophyllus* (clove) oil on *Absidia corymbifera* by comparing the formation of biofilms after treatment. Mucormycosis is a life-threatening disease caused most commonly by species *Rhizopus*, *Mucor*, and *Absidia*. The disease occurs most often in immunocompromised individuals such as burn, cancer, and diabetic patients. Amp B is the current line of treatment for the disease, but it is known to have many adverse side effects and toxicity in doses too low to manage infection. Because of the high mortality and morbidity associated with the disease even when treated with Amp B, it is vital that new combination therapeutic techniques be investigated to more effectively treat the disease. Previous work on *Rhizopus oryzae* suggests the synergistic effect of clove oil and Amp B to successfully breakdown biofilm and cause cell death. Because *A. corymbifera* is the second most common cause of mucormycosis infection after *R. oryzae*, it is important to find the synergistic effects of clove oil and Amp B on the pathogen.

POSTER

Investigation of the Synergistic Effect of *Origanum vulgare* (Oregano) Oil and Amphotericin B to Inhibit Mucormycosis-causing Species *Absidia corymbifera* Fungal Biofilm

Levi Neely, Caeleb Harris, Olga Kopp, Jedediah Orullian, and Hutch Rhees
Utah Valley University

Mucormycosis is a life-threatening disease that occurs in immunocompromised individuals, such as burn, cancer, and diabetic patients. Amphotericin B is the current line of treatment for the disease, but it is known to have many adverse side effects including cell toxicity. Because of the high mortality and morbidity rate associated with the disease even when treated with amphotericin B, it is vital that new

combination therapeutic techniques be investigated in order to more effectively treat the disease. Mucormycosis can be caused by a fungus called *Absidia corymbefiera*. This species causes up to 5% of infections and is a species isolated from confirmed mucormycosis sites. *Origanum vulgare* (oregano) oil has been shown to have broad antimicrobial properties in various studies. This study investigates the ability of oregano oil to lower the concentration of amphotericin B needed to successfully inhibit *Absidia corymbefiera* biofilms. Various concentrations of oregano oil and amphotericin B are tested to determine the optimal concentration ratio that maximizes biofilm inhibition. Synergistic activity of oregano oil and amphotericin B could be used to decrease the amount of amphotericin B needed to treat mucormycosis infections while still utilizing the antifungal properties of oregano oil.

POSTER

Lemongrass Essential Oil and Amphotericin B as Antifungal Agents against *Absidia corymbifrea* Biofilm

Stephanie Hopkins, Hannah Robb, Jedediah Orullian, Caeleb Harris, Hutch Rhees

Utah Valley University

The purpose of this experiment is to investigate the antifungal activity of lemongrass oil and amphotericin B on *Absidia corymbifrea* biofilm in an attempt to demonstrate that the minimum inhibitory concentration of Amp B can be reduced and antifungal activity maintained or increased when supplementing with the oil. *A. corymbifrea* is the second most common fungal species found in mucormycosis infections, a serious disease typically affecting individuals with weakened immune systems. Amphotericin B (Amp B) is the most common treatment for this disease, but because of documented adverse side effects including cell toxicity and high morbidity rate, there is a need for alternative treatment techniques. Essential oils derived from aromatic plants with antimicrobial properties are being explored and modified to substitute chemically based treatment options. Lemongrass oil has shown potent antimicrobial capabilities against bacteria and yeast and as such is a good candidate for this study. Each cycle of the experiment will involve *A. corymbifrea* biofilms being generated in 96-well plates. Various concentrations of lemongrass oil and Amp B will be tested to identify the optimal concentration ratio required to maximize biofilm inhibition. Following antifungal treatment, biofilms will be washed and treated with

XTT/menadione solution. After being transferred, absorbency of each plate will be analyzed and compared. We expect the synergistic use of lemongrass oil and Amp B to decrease the concentration of Amp B needed for effective treatment of opportunistic fungal diseases like mucormycosis. This reduction could decrease the side effects caused by high doses of Amp B while still maintaining antifungal activity with lemongrass oil.

POSTER

A Preliminary Study of Genetic Diversity in Ant Populations at the Southern Utah University Mountain Center

**Brent Thacker, Michael Tyler, Makayla Oborn, Emily Olsen,
Reggie Allen, Carrie Jo Bucklin, Samuel Wells**
Southern Utah University

Ants are a crucial part of a variety of ecosystems. They help to aerate the soil, which allows for water and oxygen transport to plants and other microorganisms. By studying their genetic diversity, we can better understand what is going on in a population. We studied the genetic diversity of ants collected at the Southern Utah University Mountain Center. Collected ants were from genera of *Camponotus* (n=5), *Formica* (n=219), *Lasius* (n=38), and *Pheidole* (n=42). We extracted the DNA with a DNeasy kit. We then used PCR to amplify 10 microsatellite loci. Allele calls were made using Peakscanner 2.0 and then analyzed using GenePop and FSTAT 2.913. It was found that the ant populations were not in Hardy-Weinberg Equilibrium and that the populations were genetically diverse.

POSTER

Conservation Genetics of Black Bears (*Ursus americanus*) in Southwestern New Hampshire

Kaetlyn Revels
Southern Utah University

Large mammalian species face many challenges, including habitat fragmentation and destruction, human population growth, and loss of

genetic variability. It is important to describe the genetic structure and mating systems of these species to ensure their survival. American black bears, *Ursus americanus*, range widely throughout Canada and the United States. There is a relatively large bear population in southwestern New Hampshire, but little is published about the genetic structure in this area. Extensive research has been conducted on the black bear population in Lyme, New Hampshire, by wildlife biologist Ben Kilham, Ph.D. Preliminary kinship analysis confirmed known mother-offspring relationships and suggested that multiple paternity exists. However, relatedness among the males and effective population size in the study area is not known. It is also suspected that twins are prevalent in the population, but there is no genetic evidence to support this hypothesis. A more comprehensive study is needed to further elucidate the genetic relationships of the bears residing in the study area. The main objectives of our study are to (1) estimate the rate of multiple paternity in black bear litters in southwestern New Hampshire, (2) estimate the relatedness of the male population in the study area, (3) describe the population genetic structure of the black bear population in the study area, and (4) provide evidence for twinning in the black bear. Bear samples will be provided by Dr. Kilham. This study will provide important information about the genetic structure and mating systems of the bear population surrounding Lyme, New Hampshire.

POSTER

Cancer and Heart Disease in Utah County: Do Diet and Use of Complementary and Alternative Medicine Have an Effect in their Low Incidence in the Area?

Sarah Khelfa, Kelly Greener, Andy Geigle

Utah Valley University

Heart disease and its related conditions are the leading causes of death in America, with Utah having a lower incidence, ranking 35th in the country for heart disease and 50th for cancer. This research will help shed light on what could be responsible for the lower rates in Utah, and what individuals can do to reduce their own risk of heart disease and/or cancer in other states. Utah County has a high demographic of religious individuals, in particular members of the Church of Jesus Christ of Latter-Day Saints, who have traditional beliefs regarding the use and consumption of plant-derived stimulants such as caffeinated coffee/soda/tea, alcohol, tobacco, fruits, and vegetables. We plan to

analyze the correlation between religion, the use of plant-derived substances, complementary and alternative medicines, and family medical history. Our research will be conducted through random sampling across various locations on the Utah Valley University campus. Analysis of the data on individuals (biological attributes, educational level, family medical history, consumption of caffeine, fruits and vegetables, and religious affiliations) will allow us to determine if any of these variables relate to Utah's low rate of heart disease and cancer. This research provides valuable information for the community at large.

POSTER

Bisphenol's Damaging Effects of Human Reproductive Dysfunction and Chronic Illnesses Including Hypothyroidism, Vitamin D Deficiency, and Alzheimer-like Neurotoxicity

Dominique Elder, Heather Wilson-Ashworth

Utah Valley University

Bisphenol-A (BPA) is an endocrine disrupting chemical present in polycarbonate plastics, paint, glue, and epoxy resins as well as many other household products. Because of the pervasiveness of BPA, the likelihood of individuals encountering BPA in their day-to-day lives is very high. Since this chemical does not degrade easily, it is found in abundance on the surface of water, landfills, sewage runoff, and sludge. This results in an accumulation of BPA, which may reach levels that have adverse effects on humans. Because of the structure of BPA, this molecule binds to steroidal binding sites, including estrogenic hormone receptors and vitamin D receptors, preventing estrogens and vitamin D from rendering their physiological effects. Such effects include two broad categories. First, BPA interferes with normal reproductive functions. This would include fertility and implantation. Gestational abnormalities and ambiguous sexual development are also observed. Second, BPA contributes to prevalent, chronic illnesses affecting the adult population, such as thyroid and vitamin D deficiencies, renal failure, hypocalcemia, insulin resistance, obesity, and insulin-induced Alzheimer-like neurotoxicity.

POSTER**Correlation Between Education Levels and Use of Essential Oils in a Sample Population****Meagan Griswold, Ammon Allphin, Micheal Litchfield***Utah Valley University*

Essential oils are naturally occurring compounds that are found in various parts of plants, including the leaves, stems, roots, bark, and flowers. These oils have a great diversity of uses when applying an essence, topically and/or internally. The main focus of this study is to examine whether there is a correlation between education levels and the use of essential oils. This study is valuable because it will provide insight into what drives the use of essential oils over modern medicinal techniques. The study uses a semi-structured interview design in Qualtrics, which will facilitate data gathering with recruitment of informants using social media. Essential oils are becoming widely popular and users of essential oils use them to impact emotions through the limbic system, to support health and wellness, for natural cleaning and deodorizing, and as a natural alternative to perfume among other uses. Given the wide use of essential oils in the area, we expect a great diversity of responses related to their use, allowing for the evaluation of the correlation between levels of education and use of essential oils.

POSTER**Perception of Genetically Modified Organisms for Human Consumption in Utah Valley University Students****Jason Walker, Jacee Horne, Austin Baker***Utah Valley University*

The scientific consensus on the use of genetically modified organisms (GMOs) in food is that they are safe and can provide a range of benefits over unmodified products. However, public opinion is often at odds with scientific consensus, and news and social media often propagate incorrect and conflicting information. We intend to find out how Utah Valley University students perceive the utilization of GMOs and from what sources they get their information. To perform this study, we will survey UVU students about their level of knowledge and perception of GMOs. We hypothesize that based on the amount of misinformation in

the media, UVU students will have a generally negative view of GMOs. The statistical analysis of the data will be presented. This research aims to understand the awareness and attitudes about GMOs in our area.

POSTER

Public Perception of the Use of Marijuana, Prescription Painkillers, and Opioids at Utah Valley University

Rick James, Jesse McHale, Jordan Daniels

Utah Valley University

Cannabis is widely used in the world recreationally and medically, whereas opioids are commonly used as prescription painkillers often associated with chronic pain, terminal illness, and imminent death. These drugs tend to have negative side effects, such as nausea, vomiting, diarrhea, tiredness, among others. Abuse of non-medical prescription drugs is a continually growing problem for young adults. Our study aims to analyze the perception that the general public has toward the use of cannabis compared with the use of opioids and prescription painkillers. Our demographics include people from the age of 18–30 years who are students at Utah Valley University in Orem, Utah. The selection of informants will be done at random and, after informed consent, the data will be gathered. No identifiers will be collected to allow for a candid and more truthful responses. The results will be analyzed and the correlated between the public's view on marijuana versus prescription painkillers and opioids.

POSTER

Analysis of the Knowledge of Utah Valley University Students and faculty in Identifying Common Poisonous/Hazardous Plants

Olga R. Kopp

Utah Valley University

Utah Valley has a rich culture of recreation and cultivation, both of which involve varying possibilities to come in contact with poisonous or hazardous plants. Many activities that residents frequently participate in such as hiking, biking, walking, etc. and the locations where these

activities are performed are associated with diverse populations of plants. Many of these plants are not easily recognized, including those that may be poisonous, hazardous, or not safe for consumption. The objective of this research is to evaluate how many of the commonly found poisonous plants can be identified by Utah Valley University students and faculty. This will be important because individuals who have household plants or gardens or enjoy the outdoors may be unaware of common plants that are hazardous to their health. We will be collecting data by administering a short questionnaire followed by a survey with pictures of various plants to determine the knowledge of each participant regarding poisonous plants. We will correlate the findings with demographics such as sex, family, activity level, and other parameters and the results of this research will be presented. The participants will be given valuable information about the dangers of the plants studied so they can be better informed of the potentially hazardous plants that can affect their families.

POSTER

Impact of Locular Gel on the Formation of Callus in Tomato Tissue Cultures

Arthur Evensen

Utah Valley University

Locular gel encapsulates seeds in developing fruit. It is composed of water, sugars, carotenoids, vitamin C, lectins, and growth-regulating hormones such as ABA and gibberellins. In mature seeds, cell expansion causes the locule capsule to burst and release the locular gel. Previous studies have shown that locular gel inhibits seed germination. We hypothesized that the presence of locular gel on tomato explants would have an inhibitory effect on callus formation. In our study, two tomato fruits were sterilized and segmented into 60 explants that were cultured on MS media with NAA and kinetin. Thirty explants were taken from areas in direct contact with locular gel in the tomato fruit and were cultured with locular gel residue intact. The remaining 30 explants served as controls, having no locular gel contact. All explants were incubated and evaluated biweekly for callus formation. After the eighth week of the incubation period, we found no difference in callus formation between explants with locular gel contact and the control group. Our findings led us to conclude that the presence of locular gel

has no discernable impact on callus formation in tomato fruit tissue culture.

POSTER

A New Gigantic Sea Spider in the Genus *Colossendeis*

Jordan Parker, Bonnie Bain
Southern Utah University

Pycnogonids or sea spiders are a small group of marine chelicerate arthropods (90 genera, 2,000 species). The genus *Colossendeis* contains the largest pycnogonids (leg spans up to 70 cm), which are found in very deep water and also near shore in shallower water in the polar regions. We have a number of specimen lots of *Colossendeis* sp. borrowed from the Smithsonian Institution, National Museum of Natural History and are in the process of determining whether or not any of them are new species. All are labeled as *C. colossea*, but after an examination of the type specimens for this species, it is apparent that many of these could be new species. Currently, we are examining USNM 69522, a specimen lot that contains two adults and a number of juveniles of different sizes. The project includes examining the specimens under a microscope, photographing them, documenting their morphology, measuring the trunk and appendages, and then comparing the results with the type species. Morphological structures to be examined include proboscis and mouth, eyes and eye tubercle, pedipalps, ovigerous legs, ovigerous leg spines, and walking legs.

POSTER

Proteins Observed in Honey Through Mass Spectrometry

Jeremy D. Bergman, Dac A. Crandall, Rawlings E. Lyle, Austin D. Sherwin, Trient B. Spires, J. Hayden Welch, Craig D. Thulin
Utah Valley University

The identification of proteins found in honey can provide an increased knowledge of its properties and possibly lead to a more comprehensive understanding of pollination and other aspects of honey production. Using proteomic methods including liquid chromatography coupled with

mass spectrometry (LCMS) and data-dependent acquisition (DDA), proteins can be identified by inherent properties of peptide fragmentation. Proteins that we identified with high statistical confidence included many of the major royal jelly proteins that are known products of the bee. Our results confirm observations previously published (see Di Girolamo et al., *J Proteomics* 2012, 75 (12), 3688-3693). There were lower statistical possibilities corresponding to peptide fragments of proteins that did not belong to the bee itself. These proteins identified with low statistical confidence include some plant proteins. The possibility of being able to identify the nectar source for the honey is intriguing and will be pursued. Importantly, coverage of peptides across identified proteins is modest; and many spectra that show high-quality fragmentation and would seem to be excellent candidates for identification were not in fact identified. This may indicate the possibility of extensive post-translational modification of proteins in honey. Analysis of the data from these experiments is complex and ongoing.

POSTER

Methods for the Study of Honey Proteins

Jeremy D. Bergman, Dac A. Crandall, Rawlings E. Lyle, Austin D. Sherwin, Trient B. Spires, Tyler J. Thornton, J. Hayden Welch, Craig D. Thulin

Utah Valley University

Honey, an important natural food, has been shown to have small amounts of protein, though studies of honey proteins to date have been somewhat limited. Di Girolamo et al. (*J Proteomics* 2012, 75 (12), 3688-3693) attempted analyzing honey for plant proteins using solid-phase extraction with ProtoMiner beads followed by SDS gel electrophoresis, in-gel trypsinization, and liquid chromatography-mass spectrometry (LCMS) of tryptic peptides; which resulted in the identification of a handful of proteins of insect origin. We sought to complement this method using trichloroacetic acid (TCA) precipitation, trypsin digestion, and LCMS detection and identification of proteins based on peptide fragmentation. Total honey protein was carefully quantified to assure better downstream analyses. Results from the new method show promising potential. The particular TCA precipitation protocol yielded sufficient amounts of protein for analysis. Separation of tryptic peptides by automated HPLC and detection and fragmentation of these peptides

through electrospray ionization quadrupole ion trap mass spectrometry using data-dependent collision-induced dissociation generated a fair number of identified peptides, many of which compare similarly to the results of the Di Girolamo group. Our methods portend opportunities to extend our understanding of the proteome of honey.

POSTER

Possible Plant Protein Identification within Honey's Proteome

Trient B. Spires, Jeremy D. Bergman, Rawlings E. Lyle, Austin D. Sherwin, Tyler J. Thornton, J. Hayden Welch, Craig D. Thulin
Utah Valley University

Bees are of tremendous biological importance, as they are the primary pollinators of wildflowers and most agricultural crops. Currently, not much is known about the selectivity of bee flower preferences, which would provide novel insights for agricultural beekeeping practices as well as potential biological understanding of these important and fascinating insects and their symbiotic interactions with plants. In our proteomic analysis of honey, 4 plant proteins were tentatively identified when protein extraction methods were employed that increased the liquid chromatography–mass spectrometry signal-to-noise ratio for peptides from the individual proteins within honey. These plant proteins were all from the mustard family, species *Arabidopsis thaliana*, or mouse-ear cress. *A. thaliana* is notable because it contains one the smallest diploid genomes of all flowering plants, at about 135 megabasepairs in length; and as a result, *A. thaliana* was the first flowering plant to have its genome sequenced. It is possible that proteins from other homologous plants might be reported as *A. thaliana* proteins during a proteomic database analysis because of the prominence of *A. thaliana* in the databases. Alternatively, the proteins might indeed be from *A. thaliana* itself, considering that this weed grows wild over many parts of the world. Continued research into honey's plant proteome constitutes a new frontier of meaningful investigation that has both agricultural and biological significance.

POSTER**Synthesis of Segments of the *Streptococcus pneumoniae* Serotype 23F Capsular Oligosaccharide Antigen for Pneumococcal Vaccine Development****Shenglou Deng, Paul B. Savage***Brigham Young University*

Deadly infectious diseases such as pneumonia, meningitis, and septicemia can be caused by Gram-positive bacterium pathogen *Streptococcus pneumoniae*. Out of nearly 100 pneumococcal serotypes, serotype 23F is one of the most prevalent, responsible for 9–18% of the pneumococcal invasive diseases among children under the age of 5 years. Although serotype 23F is included in all current pneumococcal vaccines, these vaccines often do not provide long-lasting protection against infection in young children and in elderly populations. Here we report a new pneumococcal vaccine design strategy and synthesis of serotype F23-based oligosaccharide antigen for vaccine development.

POSTER**Identifying Possible Correlations Between Seasonal/Pollen and Food Allergies in Utah County****Brady Smith, Kyle Swallow, Joseph Cook***Utah Valley University*

Pollen and other allergens that are produced from plants have been linked to several food allergies. Fruits and vegetables that are grown near allergen-producing plants or harvested during different allergy seasons can cause people to misinterpret their seasonal allergies for food allergies. If an individual is allergic to pollen, e.g., birch tree pollen, they may experience itching of the throat or mouth when eating an apple or cherry because of similar protein allergens present in those fruits. Our objective is to find out what food and seasonal allergies affect Utah county residents and if there is a direct correlation and trend between the two types of allergies. We will also ask whether the participants use and complementary and alternative medicine to treat their allergies. This research is designed to help Utah County residents understand the sources of allergies and to present suggestions to help them find alternate sources of fruits and vegetables that may not induce an allergic response.

In this study we will conduct structured interviews with students at Utah Valley University and other residents of Utah County. We will obtain qualitative and quantitative data using random sampling methods. We will compare the amount of people with allergies to the severity or mildness of the allergy. We will compile the data from the interviews and compare the types of food allergies people list to their experience to seasonal pollen allergens. These findings will provide a correlation between seasonal/pollen and food allergies and provide further insight to preventative care, the use of alternative medicine, and other conventional treatments. The data also provides trends across certain ethnic groups and possible susceptibility to certain allergens.

POSTER

Are Humans Just Animals? A Study of the Acceptance of Evolution

T. Heath Ogden

Utah Valley University

Evolution is central to understanding biology and health. Nevertheless, many people still do not accept evolution as a well-founded principle and mechanism of change (Pew 2016). The central research of this project is to examine the acceptance of evolution among Biology majors at the beginning and end of their undergraduate experience, the reasons as to why they accept or reject evolution, and if applicable, why they changed their minds during their undergraduate experience. Previous studies examined students' observations and knowledge of evolutionary theory and found that the degree of conflicts perceived between religion and science was negatively correlated with their knowledge of evolution. Main Objective: The objective of this research is to better understand the acceptance of evolution among students majoring in Biology. Methods: We will administer a short survey and conduct interviews with students majoring in Biology to better understand the reasons why they accept or reject evolution and why they change or do not change their minds throughout their undergraduate experience. The questions are designed to investigate the opinions of evolution and how the students changed throughout their undergraduate experience and over the course of the semester. Given the high percentage of students that are members of the Church of Jesus Christ of Latter-Day Saints, we will ask a few additional questions concerning religion and the student's knowledge of their religion's position concerning evolution. Hypotheses: We propose that

as students' knowledge of the evidence for evolution increased over their college years that acceptance would increase. We further hypothesized that religious students would have to reconcile their religion's position on science and evolution with their growing knowledge of evolutionary theory.

POSTER

Effect of Salinity on the Hatching of *Branchinecta lindahli* Packard, 1883

Fredric Govedich, Bonnie Bain

Southern Utah University

Utah is located in an arid desert environment, with many small isolated ephemeral or seasonal wetlands. As part of a multi-year study of a series of temporary rock pools in Three Peaks, Utah, we studied the lifecycle and biology of *Branchinecta lindahli* Packard, 1883. These pools fill with rain or snow and then slowly evaporate until the next storm. Fairy shrimp only hatch when there is sufficient water. In this study, we looked at salinity as a hatching trigger. The effect of salinity on hatching rates of *Branchinecta lindahli* was examined using 5 salt (NaCl) concentrations ranging from 0 g/L to 4 g/L (N = 18). A significant negative relationship ($p = 7.03 \times 10^{-3}$, $R^2 = 0.522$) was found between salt concentration and the number of fairy shrimp hatched. This supports other studies looking at hatching cues as a survival mechanism of fairy shrimp in ephemeral habitats. The avoidance of abortive hatching suggests that fairy shrimp do use a bet-hedging strategy that allows them to survive and persist in temporary wetlands. Salinity is most likely a hatching trigger used in that strategy.

POSTER

Cormorants: Where Are They During and After Fish Stocking in Suburban Ponds in Northern Utah

Nicholas Padilla

Weber State University

Double-crested Cormorant (*Phalacrocorax auritus*) foraging on fish populations has increasingly become a concern in North America. The

Cormorant is a piscivorous bird that populates a wide variety of aquatic habitats. Our research focused on the locations of the birds and their foraging activities in relation to the fish stocking dates in small suburban ponds in northern Utah. Based on a prior study, we hypothesized that the number of cormorants at each pond would increase around the stocking dates. Every morning during May 2017, we censused cormorants for 30 minutes at nine ponds. We also measured turbidity and water temperature. In general, cormorant numbers increased following rainbow trout (*Oncorhynchus mykiss*) stocking. In one case, a higher number of trout stocked was associated with the highest abundance of cormorants. In contrast, stocking of channel catfish (*Ictalurus punctatus*) was not associated with an increase in cormorants. The most turbid pond also had no fish stocking and fewest cormorant observations. This suggests the possibility that stocking lower numbers of trout more frequently could reduce attraction of cormorants.

POSTER

Brian Head Fire: Effects of Fire on Aquatic Ecosystems

Nayla Rhein, Fredric Govedich, Carrie-Jo Bucklin, Bonnie Bain

Southern Utah University

The Brian Head fire, which began because of human action in June 2017, quickly wrecked havoc in the western corner of the Dixie National Forest. It covered roughly 72,000 acres of land. The full impacts of the fire have yet to be discovered, but there is an urgent necessity to evaluate the drastic changes to the ecosystem. In this study, we aim to look into variations in water chemistry of two streams crossing the Brian Head burn scar. We will conduct weekly monitoring of the pH, dissolved oxygen, water velocity, temperature, and turbidity. Our two sites are located along the Second Left Hand Road, in Middle Creek and Parowan Creek. Our goal is to evaluate how the fire affects these streams not only through ash deposits but flooding and erosion as well. Water velocity and turbidity will be more reflective of punctual episodes of flash flooding that have occurred on multiple occasions in the Parowan area since the fire. We can see that the road and the stream banks have already been significantly altered; our study will allow us to have a deeper understanding of how the fire affected the area and its ecosystem. Future studies will include and biological assessment through the invertebrate community of the streams.

POSTER**The Ruff Life: An Approach to Undergraduate Canine Research****Peter Williams, Tasha Young, Jessica Hill***Utah Valley University*

Undergraduate research exposure is associated with improved academic performance (Ishiyama, 2002), critical thinking capacity (Landrum & Nelson, 2002), skills in data interpretation (Kardash, 2000), and student–faculty mentor relationships. These effects are most pronounced in a high-risk individuals, such as first-generation, female, and minority students (Nagda et al., 1998), who tend to participate less in undergraduate research. This is likely because of a lack of understanding on what research is, how one can participate in research, and the importance of research experience in future endeavors. In an effort to combat these problems pervasive in undergraduate research, we created a group for undergraduate research focused on canine cognition. We believe that this encourages meaningful research participation, because of the interest and familiarity of the subject matter. Students are able to extend psychological concepts and theories learned through their coursework and apply it to something both relevant and recognizable. Through doing so, students learn important research skills that can benefit them in any facet of life. Students practice analyzing research designs, thinking conceptually, and applying the scientific method toward everyday things. In this poster, we share our experiences with establishing a line of canine cognition research at a primarily undergraduate teaching institution. We will explain how to overcome common challenges and avoid potential mistakes, as well as review the various benefits of conducting this style of research.

POSTER**Diffusion-limited Titration Using Microfluidics****Christopher Monson***Southern Utah University*

We have developed a method to make microfluidic devices using a sacrificial magnesium ribbon as a template. The magnesium ribbon is shaped into the desired channel, embedded into polydimethylsiloxane, and then dissolved using a hydrochloric acid bath in a sonicator. We have

done some characterization of this fabrication method and the microfluidic devices obtained with it and have found that the devices exhibit laminar flow as expected. Turbulent flow (and thus mixing) can be induced by twisting the channel. Using this fabrication method, we have created microfluidic devices to perform a diffusion-limited titration. In this titration, acidic and basic solutions are introduced into either side of a single channel and allowed to flow next to each other. As the channel is straight, ideally no mixing occurs other than diffusion between the two solutions. The reaction is monitored using a pH-sensitive fluorescent dye (morpholine-fluorescein), so the diffusion of ions (largely H^+ into the basic solution) can be monitored using a fluorescence microscope. With this method, we hope to be able to calculate both concentrations and, to some extent, identities (at least strong vs. weak acid) of unknown solutions.

POSTER

The Destructive Effects of Radio Galaxy Jets on Neighboring Galaxies

**Taylor Morgan, Kallin Raymond, Bryan May, Kasen Lisonbee,
Jordan Memmott**

Southern Utah University

A small portion (<2%) of galaxies host black holes that are actively growing and produce energetic jets that may extend for millions of light-years beyond the host galaxy. These jets are large enough to impact nearby satellite galaxies, which may affect star formation in these satellites. This research examines the effects of the jets of a sample of 58 radio galaxies on nearby galaxies within range of the jets. The relation of neighboring galaxies to the jets is checked by visual inspection such that two samples are produced: neighbors inside the path of the jet and those outside. We compare the colors and thus the star formation rates of these samples and find an excess of blue galaxies outside the jets and red galaxies inside the jets, which suggests that the jets quench star formation in neighboring galaxies. We then evaluate the color of galaxies within the jets with respect to distance from the host galaxy. We find that there is no correlation between the star formation, or lack thereof, in a satellite galaxy and its proximity to the source of the jets. This suggests that the quenching of star formation is not influenced by distance from the jet source.

POSTER**Synthesis and Evaluation of Chalcone and Cinnamate Ester Derivatives for Anti-tumor Activity****Don Davies, Parker Ferguson, Jordan Lowder***Weber State University*

Chalcone compounds have been found to be effective at inhibiting the growth of cancer cell lines. In an attempt to discover structure–activity relationships and mechanism of action and to create substrates with increased anti-tumor activity, portions of the original chalcone structure have been modified and tested for anti-cancer activity. So far it has been discovered that substituting the 1-phenyl group with hydrogen, to produce cinnamaldehyde, or with an ester or nitro group, yielded a substrate with greater anti-tumor activity than chalcone itself. The lack of activity of substrates without the alkene group suggests the mechanism of action involves a Michael reaction. Additionally, the lack of activity of cinnamic acid, which would convert to a carboxylate salt in a basic medium, and low-molecular-weight substrates suggests the need for substrates to be neutral and lipophilic. Substrates were generally formed using an aldol condensation or esterification of cinnamic acid, using dicyclohexylcarbodiimide and a suitable alcohol.

POSTER**Carbon Pricing in the Private Sector: How the Science, and Politics, of Carbon Pricing and Climate Change Influence Business Strategy****Hayden Hubbard, McKlayne Marshall***Utah State University*

Economist Michael Greenstone called the social cost of carbon (SCC) “the most important figure you’ve never heard of.” The EPA defines the SCC as “an estimate of the economic damages associated with a small increase in carbon dioxide (CO₂) emissions, conventionally one metric ton, in a given year.” The dollar figure assigned therefore represents “the value of damages avoided for a small emission reduction (i.e., the benefit of a CO₂ reduction).” The current dollar value of a metric ton of carbon has different estimates within each company, country, and interest group. The process of calculating the SCC is immensely complex and relies on

numerous variables that are highly disputed by scientists, private interest groups, and policy makers. Our purpose is to examine motives, trends, and methodology behind public and private companies in the United States using SCC estimates.

POSTER

Validation of Self Through Dating: Correlation Between Number of Dates Asked Out On and Self-Esteem Among Female Brigham Young University Freshman

Sydney Rasmussen

Brigham Young University

This study examined the relationship between self-esteem and number of dates asked out on over the past year among female freshmen at Brigham Young University. A total of 14 participants were involved in the study, with a mean age of 18.71 ($SD = .47$). They were administered a survey through Qualtrics consisting of two parts; part one consisted of various questions pertaining to experiences and attitudes around dating, including how many dates participants had been asked out on within the past year, while part two consisted of the Rosenberg Self-Esteem scale. A Pearson product-moment correlation coefficient was used to analyze the data. The results revealed that there was a positive correlation between number of dates asked out on and self-esteem, $r(14) = .55$, $p < .05$. The results of this study suggest that a BYU freshman female's self-esteem may not be independent of the number of dates she is asked out on, supporting the initial hypothesis that the number of dates a young woman at BYU is asked out on affects a young woman's self-esteem. An unexpected finding from this study was that 100% of participants agreed they expect to be married sometime during their undergraduate experience at BYU; it is interesting to note, however, that only 27% of BYU students are married by the time they graduate with a bachelor's degree (Hollingshead, 2016). The main limitations of this study include a very small sample size, lack of control for mental health influences, and the forcing of participants to choose between "agree or disagree" on some items rather than offering a Likert scale spectrum. Further studies should examine the relationship between dating and self-esteem through quantitative methods, or examine the prevalence and extent of unrealistic expectations single female BYU students have pertaining to marriage.

POSTER**Comparing the Learning Outcomes in Chemistry Outreach Between Elementary Charter Schools and Title One Elementary Schools****Prerna Kamath, Mikayla Rosqvist, Rebecca King, Bradford Stockman***Salt Lake Community College*

For the past 15 years, our outreach program, Elemental Expeditions (EE), has built strong ties throughout the local community by promoting science, technology, engineering, and math education (STEM) to disadvantaged youth attending resource-limited schools. Through hands-on chemistry experiments, interactive lesson plans, EE has made great strides towards broadening the educational opportunities available to local title one elementary schools. For the past two years, our EE outreach program has incorporated pre and post quizzes to measure the learning outcomes. This project is an expansion of our outreach program to compare results of charter elementary school outreach with the results of title one elementary schools within the same geographic area.

POSTER**Gender Differences and The Learning Outcomes in Chemistry Outreach****Prerna Kamath, Mikayla Rosqvist***Salt Lake Community College*

For the past 15 years, our outreach program, Elemental Expedition (EE), has built strong ties throughout the local community by promoting Science, Technology, Engineering, and Math education (STEM) to disadvantaged youth attending resource-limited schools through hands-on chemistry experiments and interactive lesson plans. For the past two years our EE outreach program has incorporated pre and post quizzes to measure the learning outcomes. This study analyzes gender differences in the outcomes of our EE outreach program.

POSTER

Ablation of Materials Under Catalyzed Deuterium Flow

Mike Taggett

Southern Utah University

The presence of catalyzed deuterium on the surface of metals has been shown to cause changes in how the metal responds to pulsed laser ablation. Most of the previous research into the subject has focused on the ejecta from the catalyzed deuterium treated materials under laser ablation, but very little research has been conducted into the changes in the ablation rate of materials with catalyzed deuterium present on the surface. The effect of catalyzed deuterium on the rate at which materials ablate was studied. The change in ablation rate was studied by comparing the depth of ablation pits after being subjected to laser fire for a specified amount of time and by observing the decay time of the capacitive sensor signal during longer firings. There were marked differences in the length of signal decay time on the capacitive sensor and the depth of the ablation pits in the metal samples between before and after catalyzed deuterium accumulation. Tests of ablation without the catalyzed deuterium but instead under low to medium vacuum or normal deuterium flow do not show the same changes. Similarly, subjecting materials that are not known to accumulate the catalyzed deuterium yielded no change in signal decay or pit depth. The change in ablation rate of materials following the deposition of catalyzed deuterium is an interesting expansion on current research into this phenomenon and can serve as a method of examining the catalyzed deuterium accumulation characteristics of materials.

POSTER

Music to the Rescue: Long-Term Music Exposure Improves Anxiety and Depression Without Altering Life Satisfaction in the Elderly Living in Assisted-Living Facilities

Cody Titcomb, Jacob Peterson, Ting-yi Liao

Utah Valley University

Mental and physical health decline rapidly in people over the age of 65 years. Because of the projected growth in the population of elderly

people, there is an increased need for effective care of these individuals. Many elderly people will be living in long-term care facilities, which increases the risk for depression and anxiety. Therefore, assisted-living facilities will need to provide an environment that promotes the psychological well-being of their residents. In recent years, research has shown that music exposure can promote psychological well-being by improving cognitive functioning, anxiety, depression, and irritability in residents of assisted-living facilities. The current project assessed short- and long-term effects of passive music exposure via listening to self-selected songs on a personal iPod music player as well as active music exposure via participating in weekly music jam sessions on participant depression, anxiety, and life satisfaction levels. Depression, anxiety, and life satisfaction were assessed using the Hamilton Rating Scale for Depression, the Hamilton Anxiety Rating Scale, and Diener's Satisfaction with Life Scale. To evaluate short- and long-term effects of music exposure, the anxiety, depression, and life-satisfaction levels were reassessed 72 hours and nine months after the baseline assessments. The weekly jam sessions occurred throughout the experiment, and the playlists on the iPods were updated as needed. Repeated measures ANOVA indicated that long-term, but not short-term, active and passive music exposure reduced anxiety and depression levels without altering life-satisfaction levels in the elderly living in assisted-living facilities. Correlation analysis using the Pearson product correlation showed that these effects were independent of education levels and the duration in long-term care. Together, our data suggest that music exposure might be a useful strategy for long-term care facilities to promote well-being of their residents.

POSTER

Learn by Team Play: Engaging Youngsters to STEM Fields

Sean Brown, Zach Christensen, Conner Cox, Michael Isom, Mitch Nelson, Jared Porter

Southern Utah University

Research in child development has indicated that children's playful behavior has a positive impact on their brain development and their ability to learn. Moreover, children pay more attention to academic tasks when they play, in that cognitive scientists have found that play improves memory and stimulates the growth of the cerebral cortex. In addition,

preparing them to work in teams facilitates active participation and engagement in any learning environment, but also it provides a strong foundation to challenges in a professional workplace in the long run. Therefore, play in teams can possibly stimulate an enjoyable and immersive opportunity to engage children to challenging science, technology, engineering and mathematics (STEM) fields. Through a six-month longitudinal study at an elementary school in Utah, this research project aims to explore whether children teams, especially working on divergent problems that foster creativity and critical thinking, can be inspired and interested in the STEM fields. We explore how such innovative team play activities can be effectively designed with a goal to improve children's STEM knowledge and enhance their team performance. Accordingly, we adopted a popular LEGO MINDSTORMS technology to our STEM activities at a local elementary school's STEM Club, where the students ranging from the first grade to the fifth grade formed 6 teams with 4-7 people/team to learn and build their own robots. Building upon the well-known technology acceptance model (TAM), we are examining the students' learning effectiveness, enjoyment, and team performance through their team play with LEGO robots.

POSTER

Humanizing the Model Minority: A Literature Review of Current Research Concerning Counseling Asian American College Students

Austin Lynn

Brigham Young University

A detailed examination of the past 10 years of literature regarding the counseling of college-age Asian Americans is undertaken, with emphasis on counselor and client perspective. The applicability of Western counseling to individuals steeped in Asian culture is examined, and suggestions geared to increase counselor competency provided. Counselors' self-perceived competency and Asian American client experience are reviewed. The effects of acculturation and enculturation are discussed, with a special focus on the impact of Asian cultural values and their potential negative relationships with help-seeking attitudes. The nature, implementation, and efficacy of multicultural counseling is explored. Data comparing college-age Asian Americans to other groups is analyzed. Practical advice for counselors is given to help increase

multicultural competence and ameliorate Asian American clients' counseling experience. Directions for future researchers based on current limitations are also enclosed, with a special focus on practice-based research and a directive to examine specific subsets of Asian cultural values individually, rather than holistically. Counselors are encouraged to utilize unique aspects of Asian culture in counseling, instead of trying to force acculturation to occur. This review indicates that counselors who intentionally practice multicultural counseling can ameliorate the counseling process for college-age Asian American clients. It also urges researchers to conceptualize Asian culture not as a single value, but as multiple values (such as respect for authority, filial piety, etc.) in one domain.

POSTER

Why Words Matter: The Use of Language in Conducting Forensic Interviews on Adolescent Victims of Abuse

Mackenzie Quinton

Brigham Young University

The development of abuse protocol and the facilities designated to solve and prevent such abuse have expanded in recent years to accommodate the millions of children affected each year by both physical and sexual abuse. As forensic interview protocols have been developed to aid in the interview process, there has been a stronger focus on what that protocol should consist of. The outcome of forensic interviews conducted on adolescents often depend on the ability of the interviewer to extract a free-narrative response from the victim. There are two main interview protocols that are utilized in the United States, and they have very different main guidelines. The National Institute of Child Health and Human Development (NICHD) protocol focuses on language use in interviews whereas the Cornerhouse protocol focuses on flexibility and the individuality of the children. A child's ability to understand, or not understand, or know how to appropriately respond to questions asked will affect the course of a forensic interview. This is an issue because narrative accounts from victims are statistically the most important evidence in abuse cases. Research has been proven to show that interview success increases with a stronger focus on extracting a free narrative account of abuse, language use, the child first doctrine, and overall feelings of empathy and support extended to the child from the interviewer.

POSTER**The State of Educator Ethics Laws in the United States****Shirley Dawson***Weber State University*

This study provides a singular compilation and examination of educator ethic laws from all 50 states and the District of Columbia. Many professions have a single governing body that grants licensure and prescribes professional standards for its members. In the United States, individual states confer license and determine parameters of ethical behavior for those who teach. Thus, the education profession has multiple ethical codes that exist through numerous state laws. The purpose of the study was to survey state laws to determine the existence and substance of educator ethical codes. All states and the District of Columbia have at least one educator ethics law in statute, rule, or policy or combination of source. Collected ethics laws were examined for similarities and differences in source, construction, and content. Through coding and structure analysis, three taxonomies were identified and labeled as the Troika, Teaching Standards, and Limited Models. A geographical clustering of similar state laws was discovered. An accounting of existing state laws is provided with implications. The degree of variability and compatibility was noted and quantified in source, structure, content of state laws and geographical location.

SOCIAL SCIENCE**Empire Builders: Why Critical Race Theory Instigated an Unnecessary Break from Critical Legal Studies****W. Scott Jackson***Snow College*

Critical race theory (CRT) split off from critical legal studies (CLS) because the founders of CRT claimed that more attention was owed to racial issues. While the reasons for the division may have been laudable, they were misguided. CLS was equipped to deal with racial matters more effectively than CRT because CLS addresses, in addition to race, a range of disadvantaged groups. CLS focuses on race, gender, socioeconomic struggles, and more. Therefore, CRT may have been an important subfield of CLS, but completely abandoning CLS was detrimental to the

overall cause of all underrepresented groups that needed critical representation.

SOCIAL SCIENCE

The Matlock Effect: Psychological and Legal Implications of Media Consumption on the Presumption of Innocence

Nathan G. Caplin, Nick Marsing

Snow College

For centuries, English-speaking audiences have embraced law-inspired entertainment—from Shakespeare’s *The Merchant of Venice* (circa 1596~97) to Robert Boalt’s *A Man for For All Seasons* (1960). Shakespeare dedicated more known pages to “law than [to] any other profession.” (R.L., 2016) A glance at the Nielsen ratings confirms that crime and legal dramas are uniquely popular. Modern programming, such as CBS’s *Bull*, illustrates the public’s interest not only in the legal system, but in the psychology behind such proceedings. The ubiquity of law-inspired and crime-oriented entertainment raises questions about such media’s impact on potential jury pools. Scholars have researched media’s influence on jurors’ perceptions and how these perceptions influence jury trials—a centuries-cherished system of justice. Researchers debate the power of the CSI Effect, and while some find scant evidence in support of the phenomenon (Podlas, 2005), psychological research indicates that the CSI Effect does impact jurors (Durnal, 2010). Judges and attorneys have expressed concern regarding jury biases that may be acquired through law-oriented media. We seek to measure how potential jurors’ media choices influence their commitment to the principle of “presumption of innocence”—the constitutional benefit every juror must grant criminally accused defendants. Participants in our study will be divided into three groups. The first group will view media that portrays defendants and defense attorneys more positively; the second group will view media that portrays the prosecution more positively; and the third (control group) will refrain from law-oriented media. Participants will forego other crime-related and law-oriented media for the duration of the experiment. After viewing the prescribed legal dramas, participants will respond to a series of scenarios and questions designed to measure the participants’ commitment to the presumption of innocence. Our study measures how

certain legal dramas influence potential jurors' commitment to the constitutional principle of the presumption of innocence.

SOCIAL SCIENCE

Cosmologies and Laws in Contemporary Conflicts

Shadman Bashir

Dixie State University

The paper is a brief analysis of the existence of three different and unique entities and life forms active in contemporary global conflicts. They are artificial intelligence, humans, and souls. In conflicts, especially religious conflicts, all three play important roles in not only the actual fighting but also the process of identifying and setting up victory scenarios. This makes it very difficult to apply the humanitarian laws on and off the battlefield within such a conflict because most parties to such a conflict live in and believe in their own respective universes. Even a quick analyses of the wars in Afghanistan and Iraq is enough to prove this. These wars are being fought by all parties within a multiverse with multiple cosmologies. It will not be incorrect to classify such conflicts as "Cocktail Conflicts."

SOCIAL SCIENCE

How Does Political Uncertainty Affect Stock Prices? New Evidence from Prediction Markets

Raymond Bertheaud, Sheng Xiao

Westminster College

We examine how political uncertainty affects stock prices. We developed a new measure of political uncertainty based on daily data from prediction markets: Iowa Electronic Markets. Nobel laureate Kenneth Arrow et al. (2008; 'The promise of prediction markets.' *Science*, 320(5878), 877.) says prediction markets are forums for trading contracts that yield payments based on the outcome of uncertain events. There is mounting evidence that they can help produce forecasts of event outcomes with a lower prediction error than conventional forecasting. Our daily political uncertainty measure is the rolling standard deviation of the 'price' of the Democratic Presidential Candidate 'Contract' in

Iowa Electronic Markets, which indicates the predicted probability of the Democratic Presidential Candidate winning the election. We then empirically test the theoretical predictions of the following paper: Pastor, L., & Veronesi, P. (2012). Uncertainty about government policy and stock prices. *The Journal of Finance*, 67(4), 1219-1264. Specifically, Pastor and Veronesi's (2012) theoretical model predicts: 'Stock prices should fall at the announcement of a policy change, on average. The price decline should be large if uncertainty about government policy is large, and also if the policy change is preceded by a short or shallow economic downturn.' We use Presidential elections in the U.S. since 2000 as natural experiments to examine how political uncertainty affects stock prices. Our analysis confirms the theoretical predictions of Pastor and Veronesi (2012). Specifically, in our regressions, we find that S&P 500 index falls as political uncertainty rises before an economic downturn (2000 and 2008 Presidential elections). We also find that S&P 500 index rises as political uncertainty rises when the economy is not heading towards a downturn (2004, 2012, and 2016 Presidential elections).

SOCIAL SCIENCE

When a Mind Wanders: A Replication of Feng, D'Mello, and Graesser (2013)

Bryan Dalley, Sandra Cameron, Jessica Huffaker, Cloe Johnson, Dallin Ball

Utah Valley University

Mind wandering is a cognitive shift from a task to something unrelated, such as memories. To explain the cause of mind wandering, two hypotheses exist: the executive-resource and the control-failure hypotheses. According to the executive-resource hypothesis, task-related and task-unrelated thoughts compete for executive resources. When tasks are difficult, mind wandering occurs less often because there are less executive resources available. According to the control-failure hypothesis, related and unrelated thoughts compete for control, and mind wandering occurs when the person fails to suppress task-unrelated thoughts. When tasks are difficult, mind wandering occurs less often, but only if there are enough cognitive resources available. Because there is evidence for both hypotheses, it is unclear which hypothesis is correct. Feng, D'Mello, and Graesser completed a study (2013) to identify how text difficulty predicts mind-wandering frequency. In accordance with the executive-resource hypothesis, they found that participants were less

likely to answer correctly to a comprehension test item if they had mind wandered while reading difficult text. However, in line with the control-failure hypothesis, they found that participants were more likely to mind wander when reading a difficult sentence. Because of the replication crisis, we directly replicated their study. We obtained some similar results as Feng et al., but we also obtained results that contradict their results. When we analyzed whether mind wandering while reading difficult texts predicted reading comprehension scores, we obtained a smaller odds ratio (1.174 vs. 1.87), which indicates that the effect may be weaker. When we analyzed whether mind wandering occurred more frequently while reading difficult texts, we obtained a larger effect size (1.343 vs. 1.24), which adds additional evidence to the control-failure hypothesis. Our study is important because of its supporting evidence on the control-failure hypothesis and for its implications on the importance of replications.

SOCIAL SCIENCE

The Intersection of Marital Problems, Unhealthy Lifestyles, and Attention-Deficit Hyperactivity Disorder Challenges

Chris Anderson, Ron Hammond, Devin Gilbert, Justin Wilbert
Utah Valley University

This Institutional Review Board–approved study included a random sample of 10,000 former UVU students. It yielded 265 completed surveys and 177 surveys for married respondents. This presentation includes results from only 91 of those married respondents who were statistically compared on the basis of their Marital Problem Scale Scores being either low (bottom quartile, $N=42$) or high (top quartile, $N=49$). Factor analysis was conducted to identify scales. Bivariate correlations and frequencies were used for other considerations and analysis. T-tests were used to compare the means of each group. Results indicated that those with more marital problems scored significantly worse ($<.05$ level) on 20 out of 20 variables including marital relationship, healthy lifestyle activities, emotional issues, and other well-being measures. The results raise some concerns. Of specific concern was the overall statistically significantly higher scores high marital problem respondents were found to have in comparison to low ones. These included attention-deficit hyperactivity disorder (ADHD)-related tendencies, which interfered with the marital relationship and with the ADHD-related issue of being

dependable in their marriage. Although no causal factors can be established, there is a clear intersection of marital problems, ADHD issues, and unhealthy lifestyle choices. Implications for teaching, counseling, and health coaching with respect to ADHD, health, and marital issues are discussed (UVU IRB approval #01833).

SOCIAL SCIENCE

Adjunct Faculty: The Theory Behind Inclusion

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Adjunct faculty are a large part of university life. Research about adjunct faculty is lacking whereas research about students, tenured faculty, and faculty on track for tenure is much more prolific. How can adjunct faculty be framed to be better understood? This research explores temporary worker satisfaction and part-time worker satisfaction in an effort to better understand adjunct faculty and their unique role in the university system. Using this framework and building on previous research from Weber State University, results from a 25-question survey given to adjunct faculty will be presented within the frame of temporary workers to better understand this unique group.

SOCIAL SCIENCE

The Process of Sanctification: A Bourdieusian Approach to the Declension of Power in New England Puritan Clergy

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Snow College

In this paper, I explain the declension of Puritan power following the Great Migration up until when Massachusetts lost its charter in 1684. Historian Perry Miller argued that an overall declension in Puritan culture occurred during this period. However, that notion has been dispelled. There is a resurging field exploring declension in areas outside of Miller's scope of Puritan culture. I determine that colonial New England existed as a functional theocracy by using Pierre Bourdieu's approach to explain clerical power through symbolic and religious

capital. I explore civil and economic power struggles in the decades following the Great Migration to determine that the Puritan clergy's power is what declined during this period, not overall Puritan culture.

SOCIAL SCIENCE

United Way of Salt Lake 2-1-1: Evaluating the Effectiveness of Housing Referrals

Denise Whitney, Kerry Kennedy

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The United Way of Salt Lake connects residents all over Utah to local resources through their confidential and free 2-1-1 service. One of the most common requests they receive is referrals for affordable housing. In assessing ways that 2-1-1 can improve their services, a needs-based diagram was created to help identify common needs that people in particular situations would benefit from, such as those looking for housing. For this project, this diagram was used to broaden referrals for housing to include other needs, such as food, employment, and utility assistance. Callers who requested housing information were tracked for a period of 75 days and received a follow-up call 3-4 weeks after their initial call to assess the helpfulness of the referrals and if their situation had improved. Out of 125 callers, 44.8% participated in the survey, of which 75% were female, 41% had children, 37.5% had a disability, and 64.3% were Caucasian/non-Hispanic. These data were used to determine the effectiveness of giving more expansive referrals to those seeking housing in improving their overall situation. More results to follow.

SOCIAL SCIENCE

Spatial Patterns and Determinants of Housing Prices in Salt Lake County: Amenity, Transportation and Submarkets

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Housing prices in Salt Lake County have appreciated rapidly in recent years, creating a serious problem in affordability. Relying on the assessed property value data, this study comprehensively investigates

spatial patterns and underlying determinants of the housing market, with an explicit emphasis of the role of local environments, such as accessibility, amenities, transportation systems, and submarkets. Regarding the spatial morphology and submarkets, we developed a hybrid spatial data mining method and identified 43 housing submarkets in Salt Lake County. For determinants, with the control of submarkets and spatial heterogeneity, results of advanced hedonic pricing models with spatial econometrics and hierarchical linear modeling show that single-family home values in Salt Lake County are affected not only by structural attributes, but also by urban amenities and accessibility factors such as air pollution, forest coverage, quality of public schools, and commuting cost. Moreover, the forest coverage has more positive influences on the east side of Salt Lake County, while the negative effect of air pollution is less pronounced on housing value in the southeast. Particular attention has also been paid to the role of transportation systems. We find that the negative impacts of transportation systems such as traffic noise and air pollution are greater than the positive impact of accessibility. Single-family residents in Salt Lake County are willing to pay more to reduce environmental health risks than to get better accessibility.

SOCIAL SCIENCE

Understanding Us: Student Research to Support a Community Partner Working on Homelessness

Nikole Bench, Patricia Bernabe-Alonso, Israel Cervantes, Bianca Dellapenta, Marie Ellis, Whitney Hancock, Mackenzie Hughes, Tyler Jamieson, Ryan Johnson, Kaitlyn Keil, Kristen Kessler, Grace Lee, Zach Naylor, Carrie Parry, Dan Poole, Jennifer Salazar, Kymberly Simons, Celeste Suite, Aaron Wadley

Salt Lake Community College

Salt Lake Community College students in the SOC 2900 Doing Sociology course, in collaboration with the Social Work Association student club, have partnered with a local non-profit organization called Understanding Us. This organization currently provides several programs focusing on individuals experiencing homelessness in Salt Lake City. Currently, Understanding US is running a Tai Chi program at the downtown library. Student researchers will attend these sessions and collect preliminary demographic survey data to help the organization

better understand the population they are serving to best meet the needs of participants.

SOCIAL SCIENCE

Archaeology, Fireworks, and How to Carve a Pumpkin: Social Scientists Have All the Fun

Rob Carney

Utah Valley University

You can't fit a whale in a firework stand, but in this short essay I'm going to try. I'll discuss Bear's Ears and poor urban planning. I'll call for less politics in our holidays. And I'll share my own version of an origin story since ritual matters, landscapes matter, and the sacred isn't a commodity. These are three assertions we could poll and measure, or reach as conclusions based on observation, but satirizing the ridiculous works too, and more quickly. So given our time constraints, you can count on some of that.

SOCIAL SCIENCE

Environmental Bias and Belief in the 2017 Utah Valley University Student Population: New Ecological Paradigm Survey Results and Conclusions

Victor Barraza, Erin Call, Mikaela Watson

Utah Valley University

This study analyzes the results of the New Ecological Paradigm Survey given to Utah Valley University Students from 2017 to 2018. The state of Utah, particularly the Wasatch Front, has a unique environmental, political, and religious background. Not only is the air quality of Utah County frequently the worst in the country, nearly 60% of the population identifies as Republican, and over 80% of the population identifies as members of the Church of Jesus Christ of Latter-day Saints. Volunteers were given surveys with 19 questions concerning their attitude and beliefs on topics ranging from climate change, environmental use, and political affiliation. In total, 222 participants returned completed surveys, with a majority being students from PSY1010 General Psychology classes. In numerous responses, the survey results indicated a break in

opinion, a disconnect between how humans should act toward the environment and how the Earth can support human activity. The student body was willing to admit that climate change is directly human caused, that humanity has a negative effect on the environment, and that a major environmental catastrophe was on the horizon. But, they also believed that humans can and should modify the environment even if it would be a disastrous act, unable to be fully controllable, and unable to find a solution for. These results indicate a willingness to laissez faire environmental issues, possibly affected by the unique composition and heavily leaning independent and Republican political affiliation of the student body and of Utah County.

SOCIAL SCIENCE

Dark Sky Compliance: Measuring the Effectiveness of Outdoor Lighting Ordinances in Ogden Valley

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Urban sky glow, or the artificial brightening of the night sky over inhabited areas due to excessive or inefficient outdoor lighting, has many negative impacts in Utah's local environments, including the disruption of ecosystems, energy waste, and dimming residents' views of the night sky. Communities around Utah, including Weber County's Ogden Valley, are beginning to enact outdoor lighting ordinances to mitigate the impacts of this type of light pollution and conserve the dark night sky. However, it is still unclear how effective these lighting ordinances are in practice. In this paper, we aim to measure the impact of the Ogden Valley Dark Skies Ordinance, which was recently enacted in August 2017. Through a detailed inventory of commercial properties in the Ogden Valley, we are able to measure and map outdoor lights and signage that is in violation of the new ordinance. The purpose of this initial inventory is to establish both the methodology for the inventory and to capture the baseline of compliance at the time Weber County enacted the Dark Sky Ordinance. Later field work will use the same methodology to measure the effectiveness of the Dark Sky Ordinance in reducing the number of non-compliant commercial properties in the Ogden Valley. Both the methodology and the results of this research can help other communities around Utah measure the effectiveness of outdoor lighting ordinances, and thus establish local policy solutions to light pollution.

SOCIAL SCIENCE

Demography and Information Technology Impact Religious Commitment among Latter-day Saints in the Intermountain West

Rick Phillips

University of North Florida

Studies show that defections from organized religion are increasing in the United States. People with no religion now outnumber Roman Catholics, the nation's largest denomination. Consistent with this national trend, defections from The Church of Jesus Christ of Latter-day Saints (the LDS, or Mormon Church) are also increasing. In 1992, demographers estimated that 3–4% of people baptized into the LDS Church had defected from the faith. But in 2015, the Pew Research Center found that over a third (36%) of people raised LDS no longer consider themselves members of the Mormon Church. Thus, while the LDS Church continues to grow through missionary outreach and high birth rates, more people disaffiliate from the organization now than in recent decades. This paper uses a national, representative sample of U.S. Mormons to identify specific reasons for the increase in defections from the church. Findings show that this phenomenon is largely concentrated in Utah and adjacent states. The data suggest that changing demographics in Utah have transformed the state's religious subculture, making it easier for less-committed Mormons to leave the faith. I find limited support for the notion commonly advanced by activists and journalists that encountering information critical of the church on the internet is a significant catalyst for defection from the church.

SOCIAL SCIENCE

Marriage in the Latter Days: The Mormon Policy on Same-Sex Marriage

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Advocates for social justice in a diverse society must be careful that their advocacy does not in turn become oppressive to other vulnerable populations. Under the modern gay rights movement, a troubling dominant discourse has emerged that, if taken to an extreme, is

oppressive to the co-existing, subordinate narratives of religious minority groups such as The Church of Jesus Christ of Latter-day Saints (LDS Church). For example, the LDS Church's doctrinal view on same-sex marriage contrasts sharply from the dominant, gay-affirming discourse and as a result has been stigmatized and marginalized. In this article, I employ critical discourse analysis to examine the dominant, gay-affirming discourse and make visible the LDS Church's marginalized but co-existing and subordinate narrative. I argue that by making the narrative of this religious minority group visible, proponents of social justice are better equipped to truly advocate for liberty and justice for all populations in a new atmosphere founded on mutual respect in civic discourse.