S²ERC

SOUTHEASTERN STEM EDUCATION RESEARCH CONFERENCE

2024

JANUARY 12-13, 2024

HOSTED BY

MIDDLE TENNESSEE STATE UNIVERSITY

MURFREESBORO, TENNESSEE

18th Annual Tennessee STEM Education Research Conference
January 12-13, 2024

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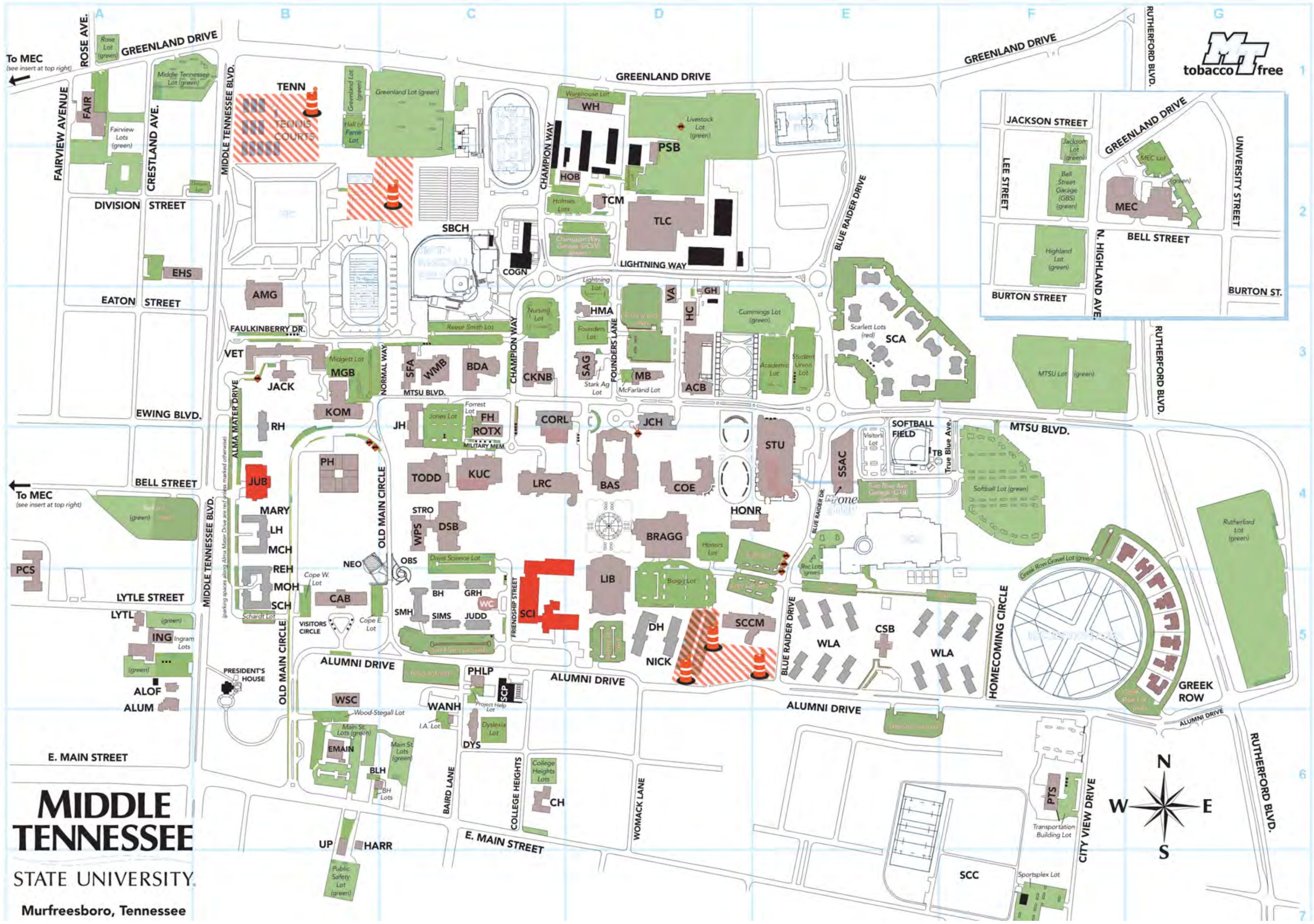
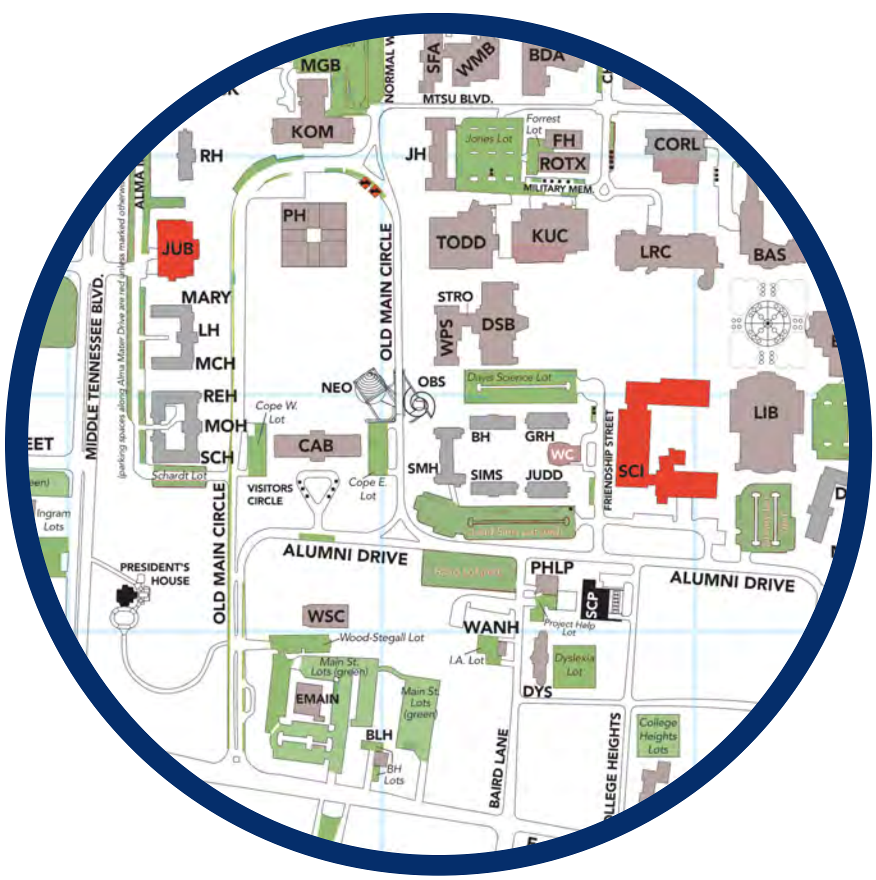


PARKING INSTRUCTIONS

All parking lots [green] will be open for the conference, no passes are needed.

Disabled parking in each lot is only available to attendees with a legal disabled parking pass.

Sessions and events will be held in the Science Building [SCI] and James Union Building [JUB] shown in red.



EVENT SCHEDULE

POSTER SESSIONS SPONSORED BY

COLLEGE OF BASIC AND APPLIED SCIENCES

MIDDLE TENNESSEE STATE UNIVERSITY

18th Annual Southeastern STEM Education Research Conference

January 12-13, 2024

Friday, January 12, 2024

11:30am – 12:30pm Tennessee STEM Education Leadership Council (TNSELC) – Science Building Room 1006

12:00pm Registration Opens – Science Building Atrium

12:00pm – 4:30pm Poster Session Setup – Science Building Atrium

1:30pm – 3:00pm Early Career Panel – Science Building Room 1006

2:00pm – 3:30pm Refreshments – Science Building Atrium

3:15pm – 4:15pm Session 1

Engineering Education – Science Building Room 1003 – (Facilitator: Lori Klukowski)

- **Improving Undergraduate Success Through Effective Critical Thinking,** *Nathan Duran-Ledezma, Joseph Biernacki, Twanelle Majors, Stephanie Wendt, & Indranil Bhattacharya (Tennessee Technological University)*
- **Pairing Sustainability with Innovation: Measuring Student Performance in a Foundry-Guided Intervention,** *Dipendra Wagale, Andrea Arce-Trigatti, Pedro E. Arce, & J. Robby Sanders (Tennessee Technological University)*

STEM Education – Science Building Room 1190 – (Facilitator: Samantha Fletcher)

- **Examining the Relationship between Classroom Assessment and Project Based Learning,** *Collin McDonald (Middle Tennessee State University) & Daniel Siao* (Auburn University)
- **IMAGES of STEM: Implications for Cohort Learning and Professional Development in Undergraduate STEM Education,** *Wanda Payne & Martene Stanberry (Tennessee State University)*
- **The Case-Based Active Science Education (CASE) Mentoring Network,** *Rebecca Seipelt-Thiemann (Middle Tennessee State University), Nancy Maroushek Boury and Patrick Armstrong (Iowa State University), Brock Couch (University of New Hampshire), Jim Haynes (Middle Tennessee State University), Olena James (Belmont University), Sayali Kukday (Iowa State University), Zach Grimes (Crowley's Ridge College), Audrey McCombs (Sandia National Labs), Nick Peters (Iowa State University) & Maartje Van den Bogaard (University of Texas at El Paso)*

STEM Education – Science Building Room 1191 – (Facilitator: Katie Coscia)

- **A Quantitative Ethnography of Computer Scientist Identity,** *Tim Ransom (Clemson University)*
- **STEM for All: TVI Perspectives,** *Lisa Salvato (Tennessee Technological University)*

4:30–5:45pm Poster Session – Science Building Atrium

Easel # Poster Title, Author(s), and Affiliations

1 • **A Conversation with Bluebot: Promoting STEM Education via Chatbots,** *Zain Al-Saad & Tisha Gaines (Belmont University)*

2 • **Analysis of Demographic and Experiential Interactions in Quantitative General Education USAFA Courses and Their Impact on STEM Attrition,** *Wilson González-Espada (Morehead State University), Capt. Scott Alsid, Maj. Daniel O'Keefe, Lt. Col. David Meier, & Maj. Christopher M. Francis (United States Air Force Academy)*

3 • **Analysis of Performance on the Praxis Biology Content Knowledge Test at the Category-level,** *Andrea Reeder & Heather Green (Middle Tennessee State University)*

4 • **Analyzing End-of-chapter Questions and In-chapter Sample Problems in General Chemistry Textbooks for Diversity of Real-world Applications and Cultural Perspectives,** *Jennifer Stockdale & Kathryn Hosbein (Middle Tennessee State University)*

5 • **Computing Education in Ghana: A Preliminary Investigation,** *Crystal Davis & Ryan A. Nivens (East Tennessee State University)*

6 • **Examining Students' Epistemic Knowledge of Atomic Structure Models in Chemistry,** *Salawat Lateef (University of Louisville), Emmanuel E. Jimenez, & Morgan Balabanoff*

7 • **Examining the Impact of Design-based Research Methods on Project Implementation,** *Skylar Hubbarth, Anna G. Hunter, Shannon Conner & D. Matthew Boyer (Clemson University)*

8 • **Exploring the Impact of a Science Communication Lesson on Undergraduate Biology Students' Ability to Communicate about Culturally Controversial Science Topics,** *Katie Coscia, Casey Epting, Alexa Summersill, M. Elizabeth Barnes (Middle Tennessee State University)*

9 • **Initial Impacts of a Community-engaged Learning Focus on Pre-service Teachers in an Early STEM Collaboration,** *Amie Perry & Alissa Lange (East Tennessee State University)*

10 • **Interdisciplinary Assessment of Student Thinking About Variability,** *Fonya Scott (Middle Tennessee State University), Rebecca Klukowski (University of Louisville), Kaytlin Campbell (Middle Tennessee State University) & Oscar Meza-Abarca (Middle Tennessee State University)*

11 • **Investigating Factors Influencing Science Student Retention,** *Hayley Benson & Morgan Balabanoff (University of Louisville)*

12 • **Investigating Pre-health Students' Science Identity and the Factors That Influence Them to Change Programs or Tracks,** *Taylor Humphreys & Morgan Balabanoff (University of Louisville)*

13 • **Investigating The Utility of and Barriers to Educational Resources for Students in STEM,** *Claire Ward & Morgan Balabanoff (University of Louisville)*

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4:30–5:45pm Poster Session – Science Building Atrium (continued)

Easel # Poster Title, Author(s), and Affiliations

14 • **Lessons Learned from the First Five Years of VolsTeach for Appalachia: Teacher Recruitment of Pre-Service STEM Community College Students,** *Nick Kim, Carlos Gonzalez & Lynn Hodge (University of Tennessee-Knoxville)*

15 • **Lessons Learned: TTU STEM Majors for Rural Teaching (SMaRT) Noyce Scholarship Program,** *Holly Anthony & Stephen Robinson (Tennessee Tech University)*

16 • **Meaningful Mathematics with Coding - Teacher Training and Collaboration with Incorporating Computer Science Principles in High School Mathematics,** *Emily McDonald (Hamilton County Schools & University of Tennessee-Knoxville)*

17 • **Measuring Goal Alignment Within a Community of Research Teams,** *Thomas Stiles (University of Montana Western)*

18 • **Metacognition in Assessing Evolutionary Understanding: A Consideration,** *Rahmi Aini & M. Elizabeth Barnes (Middle Tennessee State University)*

19 • **Parent's Early Home Math Support Does Not Correlate Between Survey and Interview Responses,** *Brooke Poston, Camille Msall, Ashli-Ann Douglas & Bethany Rittle-Johnson (Vanderbilt University)*

20 • **Parental Mathematics Support Through Pattern Activities and Talk,** *Alexis Richmond, Camille Msall, Ashli-Ann Douglas, Faith Logan & Bethany Rittle-Johnson (Vanderbilt University)*

21 • **Partnership to Develop Fermentation Science as a Curricular Enhancement to Basic Undergraduate STEM Classes,** *Tony Johnston, Terry Goodin & Ginger Rowell (Middle Tennessee State University)*

22 • **Preparing Area Pipeline Students: Evaluation of a STEM Summer Engineering Bridge Program,** *Selvam B. Pillay, K. Madeline Boykin, Jeffrey W. Holmes, Haibin Ning, Krusha Patel, Mubenga N. Nkashama & Jonathan Bonner (University of Alabama at Birmingham)*

23 • **Psychometrics of a Researcher-made Worked Examples Assessment for Math Word Problem Solving,** *Vishakha Agrawal, Anna H. Miller, Hailey Kepiro, Marcia A. Barnes (Vanderbilt University) & Sarah Powell (University of Texas at Austin)*

24 • **The Impact of Two Sequential CURES On Student Outcomes in an Introductory Biology Laboratory Course,** *Emma Throneburg, Rachel Pigg, Natalie Christian, Jeffery Masters & Mikus Abolins-Abols (University of Louisville)*

25 • **U.S. Mathematics Major Retention and Attrition: A Survey Study,** *Amanda Lake Heath & Sarah K. Bleiler-Baxter (Middle Tennessee State University)*

26 • **Use Of Smartphone Sensors to Enhance Lab Activities in an Introductory Physics Course,** *David Meier & Kimberly de la Harpe (United States Air Force Academy)*

6:00–8:00pm Dinner and Keynote Presentation – Jamies Union Building Ballroom

- Keynote Speaker - Dr. David Drew, Claremont Graduate University

Saturday, January 13, 2024

7:30am Registration Opens – Science Building Atrium

8:00am – 9:00am Breakfast – Science Building Atrium

9:00am – 10:30am Session 2

Biology Education – Science Building Room 1006 – (Facilitator: Liz Barnes)

- **Perceptions of Conflict Between Religion and Evolution are Higher Among Atheist Undergraduate Biology Students than Christian Biology Students,** *Katie Coscia, Rahmi Q. Aini, Chloe D. Bowen (Middle Tennessee State University), Sara E. Brownell (Arizona State University), & M. Elizabeth Barnes (Middle Tennessee State University)*
- **Retaining Underrepresented Students in Biology: Outcomes of a Culturally Responsive Intervention on Perceptions of Supports and Barriers,** *Carin Smith, Artenzia Young-Seigler, Elaine Martin, Jessica J. Capretto, & Marie Hammond (Tennessee State University)*
- **The Impact of Religious Identity on The Efficacy of Evolution Instruction with Cultural Competence,** *Rahmi Aini, Alexa Summersill, Casey Epting (Middle Tennessee State University), Baylee Edwards, Sara Brownell (Arizona State University), & M. Elizabeth Barnes (Middle Tennessee State University)*

Math Education – Science Building Room 1190 – (Facilitator: Kingsley Adamoah)

- **Examining Relationships Between Secondary Teachers' Content Knowledge and Attitudinal Traits,** *Christopher Bonnesen, Jeremy Strayer (Middle Tennessee State University), Andrew Ross (Eastern Michigan University), & Yvonne Lai (University of Nebraska-Lincoln)*
- **Student Perceptions of Individual and Group Creativity in Proving,** *Amanda Lake Heath (Middle Tennessee State University)*
- **Who Wrote it Better? A Comparison of AI and Teacher Created Lessons for High School Mathematics,** *Emily McDonald (Hamilton County Schools & University of Tennessee, Knoxville)*

STEM Education – Science Building Room 1191 – (Facilitator: Heather Green)

- **Assessing the Programming Self-efficacy of Teachers through Professional Development Combining Drones and STEM Activities,** *Deborah McAllister (University of Tennessee, Chattanooga)*
- **Digital Agriculture Summer Camp and Non-formal Learning: A Comparative Analysis of the First and Second Year Camp Participant Knowledge and Postsecondary STEM Interests,** *Carly Altman, Chaney Mosley, & Song Cui (Middle Tennessee State University)*
- **Enhancing STEM Learning Environments: Exploring Professional Development Opportunities in Workshops to Improve Students' Critical Thinking Skills,** *Gideon Eduah (Tennessee Technological University), Andrea Arce-Trigatti (Tallahassee Community College), & Ada Haynes (Tennessee Technological University)*

10:30am–10:45am Break

10:45am– 12:15pm Session 3

Math Education – Science Building Room 1006 – (Facilitator: Chris Bonnesen)

- **Affordances of Self-Study Methodology for Understanding Researcher Positionality,** *Samantha Fletcher (Middle Tennessee State University)*
- **Assessing Elementary Preservice Teachers' Knowledge for Fraction Division,** *Kingsley Adamoah & Jeremy Strayer (Middle Tennessee State University)*
- **The Interplay of Housing Instability and Mathematics during Adolescence: A Retrospective Study of Black STEM Folx,** *Sharetta Bufford & Eliza Gallagher (Clemson University)*

STEM Education – Science Building Room 1190 – (Facilitator: Heather Green)

- **Developing a Holistic Prototype to Wicked Challenges: A Theoretical Exploration of Graduate Student's Self-Efficacy within a Foundry-Guided Experience,** *Carey Wilson, Katie Pabody, Andrea Arce-Trigatti, Pedro Arce, Sabrina H. Buer, Ada Haynes, Rufaro A. Chitiyo, J. Robby Sanders, & Troy Smith (Tennessee Technological University)*
- **Meta-Analysis of Teaching Professional Development for STEM Graduate Teaching Assistants,** *Grant Gardner, Alyssa Freeman, Chelsea Rolle, & Kadence Riggs (Middle Tennessee State University)*
- **The Relationship between Autonomy, Pedagogical Discontentment, Self-Efficacy and the Teaching Practices of Graduate Teaching Assistants,** *Alyssa Freeman, Grant Gardner, Chelsea Rolle, Kadence Riggs, & Tom Brinthaupt (Middle Tennessee State University)*

STEM Education – Science Building Room 1191 – (Facilitator: Carly Altman)

- **Beyond Gender and Race: The Representation of Concealable Identities Among College Science Instructors,** *Carly Busch, Katelyn M. Cooper, & Sara E. Brownell (Arizona State University)*
- **The Influence of Cultural Perceptions in the Preference and Choice of STEM Programs,** *Priscilla Moffat (Ghana Institute of Management and Public Administration)*
- **The Influence of Near-Peer Mentoring on Undergraduate Career Goal Development in a Community of Research Teams,** *Thomas Stiles (University of Montana Western)*

12:15pm–1:30pm Lunch – Science Building Atrium

1:30pm– 3:00pm Session 4

STEM Education – Science Building Room 1190 – (Facilitator: Alyssa Freeman)

- **A Research-Based Dual Enrollment Statistics Class at ETSU,** *Maria Emilia Alfaro, John Hicks, & Anant Godbole (East Tennessee State University)*
- **Strategic Planning Platform for Engaged Regional Research and Industry Development,** *K. Madeline Boykin (University of Alabama at Birmingham), Gabriela Gurau, Robin Rogers, Jonathan Bonner (Unaffiliated), Jeff Gray, Chris Crawford (The University of Alabama), Tasha Drake (Stillman College), & Brian Pillay (University of Alabama at Birmingham)*

(continued)

STEM Education – Science Building Room 1190 (continued)

- **Systematic Literature Review Characterizing Students' Operational Atomic Structure Knowledge,** *Emmanuel Echeverri-Jimenez & Morgan Balabanoff (University of Louisville)*

STEM Education – Science Building Room 1191 – (Facilitator: Sarah Bleiler-Baxter)

- **Locating Holes in the Leaky Pipeline: A Quantitative Investigation into Factors and Trends Within the STEM Attrition Crisis,** *Casandra Koevoets-Beach & Morgan Balabanoff (University of Louisville)*
- **Technology-Based Programs for Preschoolers: How Does Technology-Based Interventions Close Gaps and Increase Kindergarten Readiness When Used in Pre-K Classrooms?,** *Erica Jones & Elizabeth MacTavish (University of Tennessee, Knoxville)*
- **Using Questions to Support Student Sensemaking in an Integrated STEM Investigation,** *Lori Klukowski, R. Seth Jones & Fonya C. Scott (Middle Tennessee State University)*

EARLY CAREER PANEL

FRIDAY, JANUARY 12TH, 2024
1:00PM-2:30PM
SCIENCE BUILDING (ROOM 1006)

SESSION SPONSORED BY

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EARLY CAREER PANEL

We are excited to kick off SSERC 2024 with the interactive Early Career Panel, sponsored by East Tennessee State University's Center of Excellence in STEM Education. One of the priorities of the conference is to be welcoming and beneficial for graduate students and those who are early in their career. The poster session is a part of the conference that often draws predominately from this category, or at least is easily accessible to it. One of the things we hope to encourage through events such as the Early Career Panel is the opportunity to network. We strive to bring together people at all different levels of their career, so regardless of where you are, please plan to come to the panel and the poster session to support and connect with other researchers.

PANEL MEMBERS

SAMANTHA FLETCHER

MIDDLE TENNESSEE STATE UNIVERSITY
MATHEMATICS EDUCATION

DR. TREVOR CHAPMAN

EAST TENNESSEE STATE UNIVERSITY
BIOMEDICAL SCIENCES

DR. KATY HOSBEIN

MIDDLE TENNESSEE STATE UNIVERSITY
CHEMISTRY

DR. EUNSUNG PARK

TENNESSEE TECHNOLOGICAL UNIVERSITY
LEARNING DESIGN & TECHNOLOGY

DR. ALYSSA MULLINS

TENNESSEE TECHNOLOGICAL UNIVERSITY
EXCEPTIONAL LEARNING IN STEM EDUCATION

EARLY CAREER PANELISTS

SAMANTHA FLETCHER

PhD Student, Mathematics Education, MTSU

Samanta is a doctoral student in Mathematics and Science Education, in the Mathematics Education concentration. She has prior degrees from Tennessee Technological University in Curriculum and Instruction (MA), and Secondary Education (BA). Her research interests are mathematics identity, rural education, and secondary mathematics education.

DR. KATY HOSBEIN

PhD, Assistant Professor, Chemistry, MTSU

Dr. Katy Hosbein is an Assistant Professor of Chemistry at Middle Tennessee University. Her current research projects aim to better understand how students develop a science identity by utilizing equity-centered research methods in Chemistry Education Research. She has a Masters degree in Chemistry, where she studied the diagnosis of protective coating quality on sculptures using non-destructive techniques. Dr. Hosbein earned her Ph.D. in Chemistry in 2019 from Portland State University where she researched aspects of student science and chemistry identity within general and organic chemistry courses. She then completed two postdoctoral fellowships, one at East Carolina University, where her research focused on assessing student competence in scientific practices through Argument-Driven Inquiry, and the other at the University of Michigan, where she investigated the implementation of culturally relevant education by teachers within an Indigenous community in Alaska.

DR. TREVOR CHAPMAN

PhD, Lecturer, Department of Biological Sciences, ETSU

Trevor Chapman received his PhD in Biomedical Sciences with a concentration in Physiology in 2022 from East Tennessee State University. Currently, he is a lecturer and researcher in the Department of Biological Sciences at ETSU. He teaches several sections of introductory biology I and II, supervises introductory and biochemistry laboratories, and is constructing a course on critical analysis and statistics. He co-advises several graduate students in amphibian conservation research, and is passionate about getting undergraduates involved in research.

DR. EUNSUNG PARK

PhD, Assistant Professor, Learning Design and Technology, TTU

Eunsung Park is an Assistant Professor of Learning Design and Technology at Tennessee Tech University. Her research focuses on personalized learning in advanced technology learning environments (i.e., adaptive learning, learning analytics, virtual reality, gamification), instructional design, and computational thinking. Park has taught course design and development in distance education, technology effectiveness in the workplace, computer programming, engineering MOOC, and computational thinking for higher education in addition to eight years of teaching K-12 computer science.

DR. ALYSSA MULLINS

Recent PhD graduate in Exceptional Learning in STEM Education, TTU

Alyssa Mullins earned her PhD in 2023 in Exceptional Learning with a focus in STEM Education from Tennessee Technological University where she researched characteristics of effective teaching and conducted program evaluation. She has master's degrees in Instructional Leadership from Tennessee State University, Curriculum and Instruction from Tennessee Technological University, and Education from the University of Tennessee at Chattanooga. Alyssa taught Chemistry for several years at the high school level and is currently the Dean of Students at Sequatchie County High School.

KEYNOTE SPEAKER

DR. DAVID E. DREW

CLAREMONT GRADUATE UNIVERSITY

FRIDAY, JANUARY 12TH, 2024
6:00PM-8:00PM
JAMES UNION BUILDING BALLROOM

SESSION SPONSORED BY

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Doctor of Philosophy Program

Keynote Speaker

Dr. David E. Drew
School of Educational Studies
Claremont Graduate University

David E. Drew is a Professor of Education at Claremont Graduate University in Claremont, California and holds the Joseph B. Platt Chair in the Management of Technology. His principal appointment is in the School of Educational Studies, where his teaching focuses on quantitative research methods, statistical techniques, and data analytics. For ten years Dr. Drew served as dean of the School of Educational Studies.

Dr. Drew's research interests focus on social justice and STEM (Science, Technology, Engineering, and Mathematics). His work addresses discriminatory barriers that prevent many marginalized students from accessing STEM courses. Working with school districts, colleges, and universities on programs that remove those barriers and facilitate both student access and student success. His book, *STEM the Tide: Reforming Science, Technology, Engineering, and Mathematics Education in America*, was published by Johns Hopkins University Press. He also conducts research in and writes about topics in higher education, technology, and public health. Prior to joining the CGU faculty, he held senior research positions at the Rand Corporation, the National Research Council, and the American Council on Education. Previously he had held a research faculty position at Harvard University, from which he received his PhD, and served as head applications programmer at the Harvard Computing Center.

He is the author of more than 200 publications, including 10 books, about the improvement of mathematics and science instruction at all levels of education, the development and evaluation of effective undergraduate programs, building strong university research programs, and health education.

ORAL PRESENTATIONS

AUTHORS AND ABSTRACTS

S2ERC
SOUTHEASTERN STEM EDUCATION
RESEARCH CONFERENCE

2024

Improving Undergraduate Success Through Effective Critical Thinking

Nathan Duran-Ledezmaa , Twanelle Majors , Stephanie Wendt, Indranil Bhattacharya and Joseph J. Biernacki (Tennessee Technological University)

Abstract Employers report that most of their first-time hires, usually recently graduated students, lack critical thinking skills and problem-solving dexterity. Tennessee Tech's *Undergraduate Success Through Effective Critical Thinking* (iUSE-CT) pilot study has two major goals regarding academic success and knowledge acquisition: 1) enforce first year freshmen chemical and electrical engineering students' retention rates, and 2) improve graduation rates. The methodology implemented consists of deliberately training students to identify and use critical thinking skills through individual activities as well as group tasks. Assessment is a combination of a retrospective Need for Cognition survey and pre- and post-treatment *Critical Thinking Assessment Test* (CAT). The CAT is a widely used product of a decades-long *National Science Foundation* (NSF) funded effort that assesses a well-defined range of CT skills using metacognition. The study design includes two cohorts of students divided into treatment and control groups. The design uses a two-level full-factorial matrix in which students are either included in the treatment or control groups as freshmen or sophomore students in required, critical-path courses in either chemical or electrical engineering. The courses are paired across disciplines at analogous points in the students' development and the CAT is administered at the beginning of freshman year, and again at the end of the first course (and in subsequent terms). Critical thinking training includes sessions on skills and fast-paced, in-class assignments and extended take-home work using situational open-ended frameworks. Most of the exercises are presented in a laboratory setting where students have a significantly longer class-time to accommodate extended discussion with their classmates and the instructors.

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Pairing Sustainability with Innovation: Measuring Student Performance in a Foundry-Guided Intervention

Dipendra Wagle, Andrea Arce-Trigatti, Pedro E. Arce, and J. Robby Sanders (Tennessee Tech University)

Background This contribution investigates how the role of an educational intervention that coupled sustainability principles with an innovation-driven learning platform that guided students through the development of a protype of innovative technology. Specifically, the intervention paired the Engineering for One Planet (EOP) framework with the Renaissance Foundry model (i.e., the Foundry) in an undergraduate chemical engineering course that required student teams to address technologically focused challenges (i.e. application of fluid mechanics principles) that impact environmental aspects in society as learning outcomes (Arce et al., 2015; The Lemelson Foundation, 2022). We argue that pairing the EOP framework with the Foundry Model *results in an increase in students' sustainability efforts in the design of a prototype of innovative technology (PIT) addressed in their identified challenges*. In particular, intentional activities that asked student-teams to leverage the EOP framework as a way of integrating approaches to systems thinking, knowledge and understanding, skills, experiences, and behavior as part of the design processes within Foundry-guided learning experiences were pivotal to enhance this learning environment.

Research Questions To understand the dynamics of the EOP framework and Foundry-guided course pairing, this study explores one research question: Does an RFM class framed around sustainability interventions change the ways that students incorporate key sustainability principles into design prototyping?

Methodology and Timeline The timeline for this integration started with planning and course redesign in Fall 2022, and implementation of the EOP integration in Spring 2023. Data were analyzed in Summer 2023, using a pilot design without the EOP framework integration from the Spring 2021 as a baseline. An EOP rubric was developed to reflect the nine major sustainability elements: Communication and teamwork, environmental literacy, responsible business and economy, social responsibility, environmental impact measurement, materials choice, design, and critical thinking.

Fall 2022 (Course Redesign) Leveraging funding from an American Society for Engineering Education (ASEE) faculty grant in partnership with the Lemelson Foundation, the course redesign for this study was CHE 3551 – Fluid Mechanics. Efforts for the CHE 3551 redesign in the Fall 2022 semester centered on the integration of the EOP framework as an anchoring for sustainability design elements in the prototype on innovative technology design. As a Foundry-guided course, student-team developed prototypes of innovative technology addressing societal challenges were a required outcome. The integration of the EOP framework represents an expansion of the normal course related efforts that for the last several years have leveraged the successful implementation of the Foundry (an innovation-driven learning platform) (Arce et al., 2015; Jorgensen et al., 2019). As part of this planning semester, the authors leveraged guidance from EOP content expert and the literature that framed the learning objectives for each sustainability element, the rubric depicted five measures of student performance reflective of poor (1) to excellence (5).

Spring 2023 (Course Implementation) As a Foundry-guided course, student-team-developed prototypes of innovative technology addressing technologically-focused challenges that impact the environment and the society are a required outcome. The integration of the EOP as a structured approach to sustainable design will help guide student-teams who are tasked with developing prototypes of innovative technology addressing students' identified challenges as part of these courses. Students were asked to leverage the EOP model to address challenges related to systems thinking, knowledge and understanding, and skills, experiences, and behavior and complete two activities designed to enhance their understanding of sustainability principles in design. Upon completion of the prototype of innovative technology, the rubric designed in the Fall 2022 semester was used to evaluate student performance on the prototype of innovative technology assignment that was assigned in the Spring 2023 semester, leveraging Spring 2021 data as a base comparison.

Data Analysis and Results To investigate these pedagogical claims, this study provides a statistical comparison of data collected in efforts to magnify the focus on sustainability in this undergraduate chemical engineering course at the Department of Chemical Engineering of a public, rural, four-year university. This study's research design adopts a quantitative approach that leverages a summary and basic comparison of descriptive statistics related to student performance on the nine sustainability of the EOP framework (Ary et al., 2009). To analyze differences in data collected from the prototype of innovative technology evaluations, student data reflecting two semesters was collected: one prior to, and one during, the EOP framework integration into a Foundry-guided course. Data graphics leveraged to analyze differences in student learning will feature ordinal variables reflective of student performance on the final prototype of innovative technology assignment, with summary statistics and a general distribution analysis offered (Ary et al., 2009). An overview of this analysis, the efforts of the EOP framework integration, and connections to the Foundry Model will be provided. Preliminary implications related to holistic engineering education efforts and socially relevant learning will also be presented. An overview of this analysis, the efforts of the EOP proposal, and connections to the Foundry Model are provided.

Conclusion Currently, leading national public and private organizations and foundations are strongly supporting the incorporation of sustainability in engineering education (The Lemelson Foundation, 2022). One of the leading models for guiding this effort is the EOP framework based on nine sustainability elements featured in this work. The framework is a useful organization of nine key sustainability elements anchored in guided learning objectives that align well to the engineering practice. The framework, however, lacks a pedagogical framework to guide the student systematically from, for example an environmentally driven learning challenge (identified by the student) towards the development of a PIT to address such a challenge. This study offers insight on how to leverage an innovation-driven learning approach (i.e., the Foundry) to enhance student learning with respect to sustainability elements in engineering.

References

Arce, P. E., Sanders, J.R., Arce-Trigatti A., Loggins, L., Biernecki, J., Geist, M., Pascal, J., & Wiant, K. (2015). The renaissance foundry: A powerful learning and thinking system to develop the 21st century engineer. *Critical Conversations in Higher Education, 1*(2), 176-202. Retrieved from https://www.asee.org/documents/conferences/annual/2016/Zone2_Best_Paper.pdf.

Ary, D., Jacobs, L. C., Razavieh, A., Sorensen, C. K. (2009). *Introduction to Research in Education 8th Edition.* Wadsworth Publishing, 8th edition.

Jorgensen, S., Arce-Trigatti, A., Sanders, J. R., & Arce, P. E. (2019). Promoting innovative learning strategies: A collaborative curricular re-design at the undergraduate level. *Proceedings from the American Society for Engineering Education Southeastern Conference.* March 10-12, 2019. Raleigh, North Carolina.

The Lemelson Foundation. (2022). *The Engineering for One Planet Framework: Essential Sustainability-focused Learning Outcomes for Engineering Education (2022).* The Lemelson Foundation, VentureWell, and National Science Foundation. Retrieved from https://engineeringforoneplanet.org/wp-content/uploads/2022_EOP_Framework_110922.pdf

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Examining the Relationship between Classroom Assessment and Project Based Learning

Collin McDonald (Middle Tennessee State University) & Daniel Siao (Auburn University)

Abstract Project-based learning (PBL) is a pedagogical practice that is touted for its many benefits, such as high levels of student engagement, problem solving, and developing a deep knowledge of the subject under study (Fischer, 2021; Kokotsaki, Menzies, & Wiggins, 2016; Wurdinger, Haar, Hugg, & Bezon, 2007). Incorporating class projects is a common practice in STEM courses, as STEM courses often involve complex foundational theory and abstract concepts. These projects allow students a tangible means to improve comprehension of complicated or complex subjects. This method of instruction could drastically improve course delivery as well as the foundation understanding students gain in a variety of STEM subjects, if applied.

In this presentation, we will discuss the effect of incorporating PBL in an introductory collegiate aerospace course. This course covers foundational theories and concepts related to flight through classroom lectures, writing a series of research papers, and completing a final project where students build a small, hand-launched glider. Toward the end of the semester, students launch their gliders at a height of about 20 feet, and the glide distances are measured and recorded. The level of success achieved by the glider build is determined by the glide distance. The concepts of the lectures and theory learned in class should directly assist students in completing a successful glider. This glider project bears all the characteristics of projects utilized in PBL learning: 1) centrality, 2) driving question, 3) constructive investigations, 4) autonomy, and 5) realism (Kokotsaki et al., 2016; Thomas, 2000). Ensuring that students have the proper knowledge and skills before beginning the project is one of the recommended practices of PBL (Kokotsaki et al., 2016). The researchers hypothesize that students who succeed in the academic portion of the class will also be successful in the PBL-based glider project. A dependent t-test will be utilized to determine the link between PBL and classroom success in an introductory aerospace course. The test will be utilized to determine if a connection between success in traditional assessments (quizzes and tests) correlates to success in the glide distances (longer relative glides).

References

Fischer, C. (2021). Project-based learning. Salem Press Encyclopedia.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. Improving Schools, 19(3), 267-277.

Thomas, J.W. (2000). A review of research on project-based learning. California: The Autodesk Foundation.

Wurdinger, S., Haar, J., Hugg, R., & Bezon, J. (2007). A qualitative study using project-based learning in a mainstream middle school. Improving Schools, 10(2), 150-161.

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IMAGES of STEM: Implications for Cohort Learning and Professional Development in Undergraduate STEM Educaton

Wanda Payne & Martene Stanberry (Tennessee State University)

Introduction Access to high quality education in science, technology, engineering, and mathematics (STEM) is a necessity for students to explore the opportunities, meet the challenges, and harness the power generated by innovations and advancements in STEM. For decades there has been a national emphasis on STEM education, yet disparities remain in higher education retention and graduation rates, especially for underrepresented minorities (URMs) and women in STEM disciplines. However, for the United States to remain competitive and to be more innovative and transformative in STEM, it is imperative to create learning opportunities and pathways for all students who are interested in and capable of obtaining STEM degrees and becoming STEM professionals. This is especially true at the collegiate level.

In *Charting a Course for Success: America's Strategy for STEM Education*, the National Science and Technology Council (NSTC) presented a strategic plan, including a goal to "increase diversity, equity, and inclusion in STEM by providing all Americans with lifelong access to highquality STEM education, especially those historically underrepresented and underserved in STEM fields and employment" (CoSTEM, 2018). Also included in this strategic plan were pathways to achieving its goals, and one of the pathways was "Engage Students Where Disciplines Converge." One area of focus for strengthening undergraduate STEM student progression and increasing URM participation in STEM is enhancing the first-year mathematics experience for students with mathematics-intensive academic majors, which include majors that require the calculus sequence and upper-level mathematics courses. Additionally, it is important that mathematics courses deepen the knowledge and interest of STEM students, instead of create barriers especially since STEM disciplines converge at mathematics (CoSTEM, 2018).

The National Science Foundation Historically Black Colleges and Universities Undergraduate Program (NSF HBCU-UP) through Targeted Infusion Projects supports the development, implementation, and study of evidence-based innovative approaches for making dramatic improvements in the preparation and success of HBCU undergraduate students in pursuit of STEM graduate degrees and/or careers. The funded project, Increasing Mathematics Achievement Gains by Engaging Students (IMAGES) of STEM at Tennessee State University, is enhancing the academic infrastructure of the existing STEM disciplines with mathematics intensive plans of study (mathematical sciences, architectural engineering, civil engineering, electrical engineering, and mechanical engineering). This is being done by enhancing the first-year mathematics experience of students in these disciplines. The IMAGES of STEM Project has three major components: 1. redesign of a one-semester precalculus course including algebra and trigonometry to provide a pathway for on-time graduation, 2. implementation of best practices in teaching mathematics to increase student learning and student engagement, and 3. provision of student support to promote academic and professional development.

Research Questions Several research questions were targeted for this research study. Presented here are the conclusions drawn from the results and data collected to answer the following question: *Do the cohort model and professional development activities impact STEM student motivation to persist in the academic major?*

Methodology and Timeline The timeline began with planning and course redesign during the 2021-2022 academic year and implementation beginning in the summer of 2022. Cohort 1 spanned summer 2022, fall 2022, spring 2023, and summer 2023. Cohort 2 began fall 2023.

<u>Planning: Fall 2021 and Spring 2022</u> During the Fall 2021 term, the PI and Co-PI developed the curriculum and plans for instruction for the redesigned precalculus course. The plans included various methods of instruction, i.e., face-to-face, online, and hybrid to ensure continuity of teaching and learning in the event of an emergency and to utilize learned best practices in the different teaching formats. The plan for the redesigned course was submitted to the Chair of the Department of Mathematical Sciences for final approval. In addition, the PI and Co-PI selected presenters for the STEM Student Seminar Series and made plans for face-to-face and virtual seminars to expose students to STEM professionals in industry and academia. The PI and Co-PI developed plans for identifying eligible candidates for participation in the program as scholars or peer tutors/mentors.

<u>Implementation: Summer 2022-Summer 2023</u> The IMAGES Virtual Summer Bridge Program was implemented for the first cohort of IMAGES of STEM Scholars in summer 2022. During this summer bridge program, the IMAGES of STEM Scholars received orientation that included introductions, overview of the program and its goals, description of student roles (scholars, peer tutors/mentors), schedule of activities, and expectations of the scholars.

The IMAGES of STEM Scholars took the redesigned precalculus course during the fall 2022 term, Calculus I during the spring 2023 term, and Calculus II during the summer 2023 term. The IMAGES of STEM Scholars were enrolled in each course as a cohort. Precalculus and Calculus I were taught in person, and Calculus II was taught online synchronously, and each scholar was assigned a peer tutor/mentor.

STEM Student Seminars were held with recent TSU graduates as keynote speakers. The IMAGES of STEM Scholars also participated in community building and experiential learning activities.

The first cohort of IMAGES of STEM Scholars took the Mathematics Attitudes and Perceptions Survey instrument. Their results were compared to students who were not IMAGES of STEM Scholars. The scholars of the first cohort were also interviewed to collect additional information on their perceptions.

Data Analysis and Results Data collected from the enhanced first-year mathematics experience for the first cohort of IMAGES of STEM Scholars were analyzed to determine prevailing themes in the attitudes, perceptions, and performance of the scholars and the impact of the cohort model and professional development activities. The results were coded using statistical software.

Conclusion Meeting the national need for the recruitment and retention of underrepresented minorities pursuing STEM degrees and careers requires innovations in STEM undergraduate education. Leveraging the legacy of HBCUs in producing African American professionals, HBCU-UP supports and promotes approaches to enhance and strengthen undergraduate STEM education at HBCUs. The IMAGES of STEM Project models strategies and techniques that can be scaled in full or part to help diversify the STEM workforce.

References

Andres, H. P. (2019) Active teaching to manage course difficulty and learning motivation, *Journal of Further and Higher Education*, 43:2, 220-235, DOI: 10.1080/0309877X.2017.1357073.

Code, W., Merchant, S., Maciejewski, W., Thomas, M., & Lo, J. (2016). The Mathematics Attitudes and Perceptions Survey: an instrument to assess expert-like views and dispositions among undergraduate mathematics students. *International Journal of Mathematical Education in Science and Technology* (IJMEST), http://dx.doi.org/10.1080/0020739X.2015.1133854.

Committee on STEM Education, National Science & Technology Council, the White House (2018). *Charting a course for success: America's strategy for STEM education.* Washington, DC.

O'Neill, M., Adams, M. P., Bandelt, M. J., Chester, S. A., Cai, W., & Nadimpalli, S. P. (2019). Cohort learning: Supporting transdisciplinary communication and problem-solving skills in graduate STEM researchers. *International Journal of Teaching and Learning in Higher Education, 31(1)*, 166– 175.

Woods-Warrior, E. J. (2018). Regenerating HBCU persistence and retention: Rethinking the first-year experience. *In Student Engagement and Participation: Concepts, Methodologies, Tools, and Applications* (pp. 869-898). IGI Global.

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The Case-Based Active Science Education (CASE) Mentoring Network

Rebecca Seipelt-Thiemann (Middle Tennessee State University), Nancy Maroushek Boury and Patrick Armstrong (Iowa State University), Brock Couch (University of New Hampshire), Jim Haynes (Middle Tennessee State University), Olena James (Belmont University), Sayali Kukday (Iowa State University), Zach Grimes (Crowley's Ridge College), Audrey McCombs (Sandia National Labs), Nick Peters (Iowa State University), & Maartje Van den Bogaard (University of Texas at El Paso)

Overview and Introduction A science education benefits both the country by supporting innovation, discovery, and economic stability (Carnevale et al 2011), and individuals who gain higher pay and have lower rates of unemployment. (US Bureau of Labor and Statistics, 2022). Despite the known benefits of a science career, students, particularly underrepresented students, identify biology coursework as a significant hurdle, both to remaining in science and their success in science (Lee and Ferrare, 2019; National Academies Press 2011). While many biology teachers have been working to adopt teaching practices that better support student learning and are inclusive of all students, not all teachers have made the transition to these more effective and inclusive methods (Brewer and Smith 2009). One obstacle is that many teachers lack personally connected support structures and resources, making the task overwhelming (Bathgate et al 2019; Kezar and Gehrke 2005). In answer to this need, our group has proposed and been funded to develop the CASE Mentoring Network (NSF# 2316317). The CASE Mentoring Network aims bring together motivated individuals with diverse training and backgrounds across the teaching spectrum (high school to tenured faculty), support mentoring in case-based learning (CBL) development and adoption that is focused on socio-scientific issues aligned with V&C topics, and assess the impact of CBL adoption on young scientist identity and content mastery as well as the success of the mentoring network itself using network analysis metrics.

The unique value of these case studies is that they will be involve socioscientific issues (SSI), incorporate diverse perspectives, and include elements of diversity equity, inclusion, and justice. The immediate benefit to using SSI to teach course content is students' critical examination of research to make data-driven decisions and data-grounded arguments, which allows them to situate themselves as novice scientists [Sadler and Zeidler 2010]. Students encountering the case studies in the classroom will therefore have the opportunity to not only engage with broad, interconnected scientific concepts, but also metacognitively examine and potentially identify unconscious biases that stem from belief systems (e.g., political, religious) rather than evidentiary perspectives. This will better prepare students to navigate the exceedingly complex issues faced outside of the classroom environment from a nature of science (NOS) perspective (Carter and Wiles 2014). The inclusion of NOS in the classroom through situated learning perspectives also provides a path by which students can improve their own science literacy, which is an overarching goal of science education (Roberts and Bybee 2014).

Research Questions

1. How does the CASE Network, which is based in a Community of Practice, grow and change over time?

2. Which practices best support faculty in connection and adoption of case study methodology?

3. Do the developed SSI-based case studies effectively promote the learning of science content and development of student literacy and science identify?

Methods To investigate these questions, we will:

1. evaluate the growth and success of the CASE Mentoring Network using tools for social network analysis (SNA) and expand those tools to accommodate dynamic networks that change over time. Collaboration network data will be collected from the collaboration software tool (e.g. Slack) as well as a monthly survey that measures the number, direction, and type of interactions between pairs of participants within and among pods.

2. assess faculty acceptance of CBL using the Stages of Concerns questionaries (Hall and Hord 2020) associated with the concerns-based adoption model (CBAM), as well as short interviews with participants related to their experiences with implementing CBL and focusing on their concerns and perceived levels of mastery. The questionaries will provide both qualitative and quantitative data through systematic coding of responses. Additionally, Mentors, Peer Mentors, and Fellows will write a short reflection which will be coded for themes to identify barriers to implementation, successes, and opportunities for growth.

3. assess for student gains in science literacy skills, content knowledge, and feeling of science belonging. Measurement in science literacy skills can be evaluated using the TOSLS developed skill set (Gormally et al 2012). Content knowledge gains can be measured by using pre/postests from content-specific concept inventories/criterion-referenced tests. Science belonging and motivation can be assessed using CLASS-BIO (Semsar et al 2011).

Summary of Findings

We have no findings yet to report as this project officially begins in January 2024 and will extend for 5 years. We hope to use this platform to recruit a diverse group of interested faculty and also to inform our fellow teachers and education researchers of this project and its expected products.

References

Bathgate, M.E., et al., Supports: A key factor in faculty implementation of evidence-based teaching. CBE—Life Sciences Education, 2019. 18(2): p. ar22.

Brewer, C.A. and D. Smith. Vision and Change in Undergraduate Biology Education. 2009. Washington DC: Carol A. Brewer and Diane Smith

Carnevale, A.P., N. Smith, and M. Melton, STEM: Science Technology Engineering Mathematics. Georgetown University Center on Education and the Workforce, 2011.

Carter, B.E. and J.R. Wiles, Scientific consensus and social controversy: exploring relationships between students' conceptions of the nature of science, biological evolution, and global climate change. Evolution: education and outreach, 2014. 7(1): p. 1-11.

Gormally C, Brickman P, Lutz M. 2012. Developing a test of scientific literacy skills (TOSLS): Measuring undergraduates' evaluation of scientific information and arguments. CBE—Life Sciences Education 11:364-377.

Hall, G. and S. Hord, Implementing change: Patterns, principles, and potholes . Hoboken. 2020, NJ: Pearson

Kezar, A. and S. Gehrke, Communities of Transformation and Their Work Scaling STEM Reform. Pullias Center for Higher Education, 2015.

Lee, Y.-G. and J.J. Ferrare, Finding one's place or losing the race? The consequences of STEM departure for college dropout and degree completion. The Review of Higher Education, 2019. 43(1): p. 221-261

National Academies Press. Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads. 2011.

Roberts, D.A. and R.W. Bybee, Scientific literacy, science literacy, and science education, in Handbook of research on science education, Volume II. 2014, Routledge. p. 559-572.

Sadler, T.D. and D.L. Zeidler, Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 2009. 46(8): p. 909-921.

Semsar K, Knight JK, Birol G, Smith MK. 2011. The Colorado learning attitudes about science survey (CLASS) for use in biology. CBE—life sciences education 10:268-278.

US Bureau of Labor Statistics. Employment Projections. 2022, United States Department of Labor.

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A Quantitative Ethnography of Online Computer Scientist Identity

Tim Ranson (Clemson University)

Introduction Professional identity is a core component of maturation [1] into adulthood and has been positively correlated to success in higher education [2]–[5]. Students construct their knowledge of a professional identity from many sources, including the perceptions they gather from online communities organized around the profession. Online communities present students with accessible, interactive, and anonymous sources of knowledge about the relevant professional identity. The constructed conception of who computer scientists are can act as a magnet or barrier to computer science education depending on how the profession is presented to potential computer scientists. Educators need to be aware of the ways that computer scientists are portrayed online to support or correct the understandings that students bring to classrooms about the profession. This work uses the theoretical framework presented by Große-Bölting et al. [6] to operationalize the computer science professional identity. Subconstructs of computer science identity in this framework include performance/competence, interest/motivation, values/responsibility, and recognition (by others). The Große-Bölting et al. [6] computer science identity framework extends the work of Carlone and Johnson [7], and Hazari et al. [8] with the inclusion of professional values and responsibilities.

Social media usage rates among traditionally aged college students are extremely high [9], informing their conceptions of identity [10]. Reddit is a forum-based social media platform which hosts several computer science related communities which users can access to learn what computer science is and who computer scientists are [11]. Reddit is organized into sub-forums (called "subreddits" colloquially) centered around topics such as computer science, programming, or computer science career questions. All of these online community's present characteristics of the professional computer science identity to users through the sum of linguistic references to the identity.

The large volume and variety of information referencing the computer scientist identity on Reddit presents an issue for traditional education research analysis methods. This work uses a quantitative ethnography methodology to process the large volume and the computer science identity theoretical framework presented by Große-Bölting et al. [6] to interpret the wide variety of computer science identity references.

Research Questions

1. How is the computer scientist identity portrayed in online communities?

2. How do online spaces differ in their portrayal of computer scientists?

Methodology and Timeline A quantitative ethnography [12] is currently being conducted to process and analyze Reddit social media posts using the R programming language. Quantitative ethnography is a novel methodology to apply to identity research, is able to be used to construct valuable information from social media, and responds to calls from identity literature for computational methodologies [13]. Data has been collected from online communities hosted on the popular social media platform Reddit. These online communities include a professional discussion group (r/cscareerquestions), groups discussing learning programming (r/learnpython, r/learnprogramming, r/programming), and a general computer science community (r/computerscience).

Posts that mention the term "computer scientist" from 2017 to 2022 have been collected. This time frame has been selected to correspond to social media posts which students currently enrolled in computer science programs could have seen before enrolling in college. There are over 2,500 social media posts collected that meet these filter criteria.

Quantitative ethnographies use a set of manually created qualitative codes to bootstrap the semi-automated qualitative coding process. These codes are sets of regular expressions which can be interpreted as presence of a concept. For example, when detecting references to computer scientist salary, the words “compensation,” “pay,” or “income” may all be used to refer to the same concept. Qualitative codes are generated using the Große-Bölting et al. [6] computer science identity theoretical framework. This work will report the statistical value of Cohen’s kappa to indicate agreement between the human coders and the machine coder (interrater reliability). This computational augmentation of human created qualitative codes is what allows this work to address the large volume of data.

Data Analysis & Results Data will be interpreted through an epistemic network analysis [14], which will indicate the prevalence of and strength of connection between the qualitative codes. The interpretation of the networks is guided by the author's status as a computer scientist and validated through weighted network summary statistics. All software and results will be published online through the open-source code hosting platform GitHub and written in a literate programming style to encourage replication and extension.

Conclusion Understanding the perceptions of computer scientists presented through social media indicates educators’ potential misconceptions about the profession that students bring to classrooms. Using the Große-Bölting et al. [6] framework of computer science identity indicates to educators which perceptions to reinforce or correct about computer science identity to facilitate the educational advantages of professional identity development in their students. Conducting a quantitative ethnography informs of a distributed understanding of the construction of identity and investigates the impacts of social media on the development of professional identity.

References

[1] E. H. Erikson, Identity and the Life Cycle. W. W. Norton & Company, 1994.

[2] F. Fernandez, M. Froschl, L. Lorenzetti, and M. Stimmer, “Investigating the importance of girls’ mathematical identity within United States STEM programmes: a systematic review,” *Int. J. Math. Educ. Sci. Technol.*, vol. 0, no. 0, pp. 1–41, Jan. 2022, doi: 10.1080/0020739X.2021.2022229.

[3] R. F. Baumeister, “Chapter 26 - Identity, Self-Concept, and Self-Esteem: The Self Lost and Found,” in *Handbook of Personality Psychology*, R. Hogan, J. Johnson, and S. Briggs, Eds., San Diego: Academic Press, 1997, pp. 681–710. doi: 10.1016/B978-012134645-4/50027-5.

[4] W. L. Heppner and M. H. Kernis†, “High Self-Esteem: Multiple Forms and Their Outcomes,” in *Handbook of Identity Theory and Research*, S. J. Schwartz, K. Luyckx, and V. L. Vignoles, Eds., New York, NY: Springer, 2011, pp. 329–355. doi: 10.1007/978-1-4419-7988-9_15.

[5] M. S. Ross, J. L. Huff, and A. Godwin, “Resilient engineering identity development critical to prolonged engagement of Black women in engineering,” *J. Eng. Educ*., vol. 110, no. 1, pp. 92–113, Jan. 2021, doi: 10.1002/jee.20374.

[6] G. Große-Bölting, D. Gerstenberger, L. Gildehaus, A. Mühling, and C. Schulte, “Identity in Higher Computer Education Research: A Systematic Literature Review,” *ACM Trans. Comput. Educ.,* Jun. 2023, doi: 10.1145/3606707.

[7] H. B. Carlone and A. Johnson, “Understanding the science experiences of successful women of color: Science identity as an analytic lens,” *J. Res. Sci.* Teach., vol. 44, no. 8, pp. 1187–1218, 2007, doi: 10.1002/tea.20237.

[8] Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan, “Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study,” *J. Res. Sci.* Teach., vol. 47, no. 8, pp. 978–1003, 2010, doi: 10.1002/tea.20363.

[9] A. Perrin, “Social media usage,” *Pew Res. Cent.*, vol. 125, pp. 52–68, 2015.

[10]K. Davis and E. Weinstein, “Identity Development in the Digital Age: An Eriksonian Perspective,” in *Identity, Sexuality, and Relationships among Emerging Adults in the Digital Age*, IGI Global, 2017, pp. 1–17. doi: 10.4018/978-1-5225-1856-3.ch001.

[11]Y. Kou, C. Gray, A. Toombs, and R. Adams, *Knowledge Production and Social Roles in an Online Community of Emerging Occupation: A Study of User Experience Practitioners on Reddit*. 2018. Accessed: Sep. 15, 2023. [Online]. Available: http://hdl.handle.net/10125/50148

[12]D. W. Shaffer, *Quantitative ethnography*. Lulu. com, 2017.

[13]M. Watzlawik and A. Born, *Capturing Identity: Quantitative and Qualitative Methods*. University Press of America, 2007.

[14]D. Bowman et al., “The Mathematical Foundations of Epistemic Network Analysis,” in *Advances in Quantitative Ethnography*, A. R. Ruis and S. B. Lee, Eds., in Communications in Computer and Information Science. Cham: Springer International Publishing, 2021, pp. 91–105. doi: 10.1007/978-3- 030-67788-6_7

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STEM for all: TVI perspectives

Lisa Salvato (Tennessee Technological University)

Introduction This study focused on the challenges faced by students with visual impairments (SVI) in the context of STEM education, with a specific focus on the perspectives of Teachers of the Visually Impaired (TVI). According to CDC statistics, 3% of children under 18 have visual impairments or are legally blind, this is known as a ‘low-incidence’ and ‘high-need’ disability (Petroff & Ryles, 2010). Additionally, Petroff & Ryles (2010) stated that despite this there is a scarcity of specialized programs and teachers to address the unique educational requirements of SVI. Previous studies emphasized the shortage of training programs for TVI and their discomfort in teaching STEM subjects to SVI, contributing to the underrepresentation of SVI in STEM fields (A. Adelakun, 2020). The lack of proper training and resources may lead to discouragement among SVI to pursue STEM education (Rattan, et al., 2015).

Existing literature demonstrated varied attitudes among TVI globally. Some TVI believed in inclusive education, encouraging SVI to participate fully, while others expressed reservations about the pace of instruction and felt SVI should attend specialized schools. Teachers in the U.S. and international contexts stressed the importance of adapting teaching methods and utilizing multi-sensory approaches for SVI. They advocated building prior knowledge and using tools like tactile teaching models and 3-D printed Braille resources. Additionally, metaphors used by TVI, such as TVI as guides and SVI as diamonds, reflected the unique relationship between them and indicated the potential impact of teacher perspectives on SVI’s STEM identity (Asaman, Cakir, & Aksan, 2016).

The literature review also highlighted the scarcity of U.S.-based studies on this topic. It noted the challenges faced by SVI globally and drew attention to the success of certain developing countries like India and South Africa in promoting STEM education among marginalized groups.

Research questions This study aimed to explore the perspectives of three TVI teaching STEM to SVI in Tennessee. The study sought to answer two primary research questions:

1. How do three TVI describe their experiences teaching STEM to SVI?

2. What do these perspectives suggest about dominant teacher practices and preparatory courses for TVI in Tennessee?

Methodology and Timeline Recruitment of participants began in August 2022. TVI who had three or more years’ experience teaching a STEM subject to SVI were eligible to be participants. In-person interviews were conducted in October 2022 followed by a focus interview in November. Data were analyzed in Spring 2023.

Data Analysis & Results Using poetic inquiry, an arts-based research method, the perspectives of three TVI teaching STEM subjects to SVI were explored. Transcription and coding were performed to identify keywords and phrases from the participants’ words. This process, known as “sifting,” in poetic inquiry, allowed for a detailed understanding of the participants’ experiences. Patterns and related categories were organized into themes. The final stage of the analysis involved creating found poems. These poems, derived from the participants' words and experiences, painted a vivid picture of the challenges, triumphs, and perspectives of the TVI who taught STEM to SVI.

Conclusion The findings of the study reflected the multifaceted experiences and challenges faced by TVI in the realm of STEM education for SVI. The study revealed the transformative process of becoming a TVI, highlighting the influence of social cognitive theory, social disability theory, and universal design theory. Despite challenges and feelings of isolation, TVI exhibited an unwavering dedication and embraced innovative teaching methods and technologies to empower their students. The study underscored the crucial role of support systems, inclusive educational approaches, and a redefined understanding of STEM education to ensure the success and inclusion of SVI in the realm of science, technology, engineering, and mathematics.

References A. Adelakun, D.S. (2020). Exploring STEM kit diagrams for braille readers in inclusive classrooms. *The Journal of Science Education for Students with Disabilities*, 23(1), 1-10. https://doi.org/10.14448/jsed.12.0014

Asaman, E., Cakir, O., & Aksan, Y. (2016). Seeing darkness, hearing silence: Student and teacher metaphors in the context of visually and hearing impaired. *International Online Journal of Educational Sciences*, 8(3). https://doi.org/10.15345/iojes.2016.03.003

Petroff, J., & Ryles, R. (2010). Teacher training, present and future. from https://nfb.org/sites/default/files/images/nfb/publications/fr/fr29/4/fr290406.htm

Rattan, A., Savani, K. Chugh, D., & Dweck, C. (2015). Leveraging mindsets to promote academic achievement. *Perspectives on Psychological Science*, 10(6), 721-726. https://doi.org/10/1177/1745691615599383

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Perceptions of conflict between religion and evolution are higher among atheist undergraduate biology students than Christian biology students

Katie Coscia, Rhami Aini, Chloe Bowen (Middle Tennessee State University), Sara Brownell (Arizona State University), & Elizabeth Barnes (Middle Tennessee State University)

Background The theory of evolution is one of the core concepts in biology, yet it remains highly controversial in society. Although it unifies all biological disciplines, there is a divide in society and many people are reluctant to accept it due to a perceived conflict between religion and evolution. Many people, including undergraduate biology students, perceive that religion and evolution are mutually exclusive and that an individual cannot simultaneously believe in God/god(s) and accept evolution (Barnes et al., 2020). While the perceived conflicts between religion and evolution have been measured previously, the focus has predominantly been on religious students (Holt et al., 2018; Sbeglia & Nehm, 2020), leaving the perceptions of conflict in non-religious undergraduate students relatively unexplored. In the general public, non-religious individuals tend to perceive more conflict between religion and science (Leicht et al., 2022), but we currently don't know if this extends to undergraduate biology students.

Given that our undergraduate biology students are the next generation of scientists and science educators, their perceptions of conflict between religion and evolution may potentially affect how they communicate about evolution to their religious peers and how they teach evolution to their own students in the future (Barnes & Brownell, 2016). Since non-religious individuals can also perceive conflict between religion and evolution, if our non-religious undergraduate biology students perceive high levels of conflict between the two, they may pass their conflicted views on to their peers and their future students.

Research Questions

1. What are the levels of perceived conflict between religion and evolution among undergraduate biology students?

2. Are the levels of perceived conflict between religion and evolution different between students of different religious and non-religious affiliations?

3. Why do atheist undergraduate biology students think that evolution and God/god(s) are compatible or in conflict?

Research Design We developed a novel survey measure of perceived conflict between religion and evolution that functions for both religious and non-religious students and administered it as part of a survey sent to over 11,000 students in mostly introductory college biology classes in fourteen states.

Data Analysis & Results Factor analysis of the novel survey measure revealed two separate constructs contained within the instrument, one for perceived conflict between religion and evolution and one for perceived compatibility. Hierarchical linear modeling and pairwise contrasts of estimated marginal means showed that atheist students had higher perceived conflict levels ($p < 0.001$) and lower perceived compatibility levels ($p < 0.001$) between religion and evolution than Christian students, suggesting that they may perceive more conflict and less compatibility than their Christian peers.

In order to determine potential reasons that atheist students perceived conflict or compatibility between religion and evolution, we examined open-ended responses to a survey question where students were also asked why they thought that evolution, according to the scientific viewpoint, is agnostic or atheistic about the involvement of God/god(s) in the evolutionary process. After limiting responses to only atheist students (n = 845), inductive thematic analysis (Glaser & Strauss, 2017) was used to identify common themes and iteratively develop a codebook that was used to code all 845 responses. Proportions of responses containing each code were calculated. We found that most frequently, atheist students who perceived conflict between religion and evolution tended to conflate their own atheistic views with the scientific viewpoint. Atheist students who saw compatibility tended to see more distinct boundaries between religion and science, often acknowledging that they serve different purposes or can answer different questions.

Contributions Previous work suggests that if we want to improve attitudes towards evolution, then highlighting potential compatibility between religion and evolution is important when communicating to the public and to students. These findings suggest that non-religious undergraduate biology students who perceive conflict between religion and evolution may pass their views on to their peers and their future students. Past research shows that evolution instruction that acknowledges potential compatibility between religion and evolution helps religious students reduce their perceived conflict, so future research should explore whether this instruction could reduce conflict among non-religious students, which may in turn help them promote potential compatibility when they communicate about evolution in their future roles as scientists and science educators.

References Barnes, M. E., & Brownell, S. E. (2016). Practices and Perspectives of College Instructors on Addressing Religious Beliefs When Teaching Evolution. *CBE—Life Sciences Education,* 15(2), ar18. https://doi.org/10.1187/cbe.15-11-0243

Barnes, M. E., Dunlop, H. M., Sinatra, G. M., Hendrix, T. M., Zheng, Y., & Brownell, S. E. (2020). "Accepting Evolution Means You Can't Believe in God": Atheistic Perceptions of Evolution among College Biology Students. *CBE—Life Sciences Education*, 19(2), ar21. https://doi.org/10.1187/cbe.19-05-0106

Glaser, B. G., & Strauss, A. L. (2017). *Discovery of Grounded Theory: Strategies for Qualitative Research*. Routledge. https://doi.org/10.4324/9780203793206

Holt, E. A., Ogden, T. H., & Durham, S. L. (2018). The positive effect of role models in evolution instruction. *Evolution: Education and Outreach*, 11(1), 11. https://doi.org/10.1186/s12052-018-0086-6

Leicht, C., Sharp, C. A., LaBouff, J. P., Zarzeczna, N., & Elsdon-Baker, F. (2022). Content Matters: Perceptions of the Science-Religion Relationship. *The International Journal for the Psychology of Religion,* 32(3), 232–255. https://doi.org/10.1080/10508619.2021.2003111

Sbeglia, G. C., & Nehm, R. H. (2020). Illuminating the complexities of conflict with evolution: Validation of the scales of evolutionary conflict measure (SECM). Evolution: Education and Outreach, 13(1), 23. https://doi.org/10.1186/s12052-020-00137-

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Retaining Underrepresented Students in Biology: Outcomes of a Culturally Responsive Intervention on Perceptions of Supports and Barriers

Carin Smith, Arenzia Young-Seigler, Elaine Martin, Jessica Capretto, & Marie Hammond (Tennessee State University)

Introduction Career development provides an avenue for educators to help shape students' academic interests, career goals, and expectations, as well as facilitate the development of relevant skills (Lent et al., 2005). Undergraduate education has been identified as the time when most educational and career choices are shaped, rendering career development during this time particularly salient (Sharf, 2016). Research suggests that African American undergraduate students may have unique career development needs as compared to those of White students. This may occur because these students face additional barriers, such as discrimination and internalized negative stereotypes (Gysbers et al., 2014). African American students may also have different career decision-making attitudes and work values that are not adequately considered in current career development theories (Fouad and Bingham, 1995).

While career development interventions promote students' commitment to their education and academic achievement (Fouad and Bingham, 1995; Brown and Krane, 2000), many career development methods are normed on European groups and should not be applied across cultural groups (Worthington et al., 2000). This study utilizes a culturally responsive intervention, Social Cognitive Career Theory (SCCT) with the aim of improving retention of underrepresented biology students.

Research Questions

1. What differences are observed in measures on supports and barriers between sexes?

2. Is there a differential impact of the intervention on measures of supports and barriers by sex?

3. What is the impact of socioeconomic status and parental education levels on measures of supports and barriers?

Methodology The study included 208 underrepresented minority undergraduate students (N = 79.6% African American) enrolled in STEM fields at an HBCU. A cohort method was utilized, with sections of first- and secondyear biology courses selected for inclusion in the study. Faculty teaching these courses were contacted and asked for permission to incorporate the interventions into their classes. Course coordinators identified sections of the courses to be utilized as control groups. An alternative assignment was provided by the instructor for individuals who would prefer not to participate. Participants completed a demographic questionnaire and the STEM Contextual Supports and Barriers Scale (SCSBS) (Lent et al., 2003) and the STEM Environmental Supports and Barriers Scale (SESBS) (Lent et al., 2005) as a part of a larger study. The STEM Contextual Supports and Barriers Scale (SCSBS) (Lent et al., 2003) asked participants to indicate how likely they would be to experience the conditions described in each of the 15 supports (e.g., "get encouragement from your friends for pursuing this major") and 23 barriers (e.g., "feel pressure from parents or other important people to change your major to some other field"). A five-point Likert scale ranging from 1 (not at all likely) to 5 (extremely likely) was used to assess perceived environmental supports and barriers relative to pursuit of a STEM major. SESBS is comprised of nine items, which assess social environmental supports and barriers. Participants were asked to indicate how much they were helped by four supports (e.g., “financial assistance”) and hindered by five barriers (e.g., “financial concerns”) during their first year as a STEM major. Responses were given using a five-point Likert scale ranging from 1 (not at all likely) to 5 (extremely likely).

The intervention utilizing the Social Cognitive Career Theory (SCCT) was implemented with students enrolled in general biology courses. Graduate-level psychology majors trained in career development/vocational psychology facilitated the interventions, which were delivered as sixteen 30- to 45-minute sessions per class period for an accumulated total of eight hours. During this time, facilitators presented information to the students and engaged them in activities targeted at assisting in developing the skills needed to manage their careers in biology.

Data Analysis Data were screened for incomplete responding, outliers, and assumptions with satisfactory results. To facilitate analyses, change scores were created. Post hoc power analysis indicated that power was adequate to conduct analyses ($1-\beta = 0.906$ for repeated measures, with in-between interaction) (Faul et al., 2007). An independent samples t-test was conducted to examine if differences on the measures of supports and barriers existed between groups based on sex. A one-way between-subjects ANOVA was conducted to compare the effect of socio-economic status (SES) on perceived supports and barriers. SES was divided into three conditions: upper class, which consisted of students identifying as “upper-middle” or “upper” class, middle class, and lower class, which consisted of students identifying as “lower-middle” or “lower” class. A one-way between-subjects ANOVA was conducted to determine if there were significant differences in perceptions of supports and barriers depending on parental education levels.

Summary of Findings The sample consisted predominantly of first-year students (32.6% first years, 18.0% sophomores, 23.2% juniors, 20.9% seniors, and < 5.0% fifth-year seniors or beyond) whose ages ranged from 18 to 53 years old ($m = 21.43$, $sd = 4.711$). Over half of the sample identified themselves as female (68.7%; $N = 145$), and 28.9% identified them- selves as male. The majority of the sample indicated parental education as obtaining less than a baccalaureate degree (63.3% of fathers; 56.6% of mothers). Regarding socioeconomic status, 47.9% ($N = 101$) of participants identified as middle class, 29.0% identified with lower or lower middle class, 16.6% identified as upper or upper middle class, and 6.7% declined to report. Eighty-one students completed all parts of the study, allowing for 81 matched pairs to be analyzed; 56 of whom were exposed to the intervention.

Results suggest that the intervention affected student’s perceptions of supports and barriers. After the intervention, STEM student awareness of supports and barriers increased and resulted in a decrease in perceptions of social support as compared to the control group. Furthermore, the intervention appears to mediate the influence that parental education has on the perceptions of supports and barriers. Significant differences were found between students identifying as low-middle or lower class when compared to those identified as upper or middle class in terms of perceived supports. In terms of gender, there was no significant difference between males and females in their perceptions of supports and barriers. Of note, results indicated that there were significant differences in how individuals identifying as lower-middle or lower class identify STEM supports and environmental supports compared to those of higher SES. Furthermore, no significant difference was found between the groups in terms of measures of barriers.

Conclusions and Educational Implications Due to the high enrollment of African American students at HBCUs compared to the national average of 13% (NSF, 2016), our institution is an ideal environment to investigate the issues surrounding the career choice, major field of study, persistence, and graduation of African American students in STEM. According to a National Student Clearinghouse Research Center report (2017), retention and persistence remains lowest for African American students in comparison to other ethnic groups. Furthermore, retention and persistence for first-year students over the age of 24 is lower than other age groups. The 2016 NSF data reports that African Americans represent only 9.01% of graduates across the sciences (NSF, 2016). These statistics indicate the urgency to address the culturally specific needs of students at HBCUs and other MSIs that may not exist at PWIs. There is a need to understand not only the social and cultural differences that are idiosyncratic to the African American student but also to examine the role of the students' perception of supports and barriers in relation to these idiosyncrasies that have been shown to contribute to their success or lack thereof. To better determine the effects of the culturally competent SCCT intervention on students' perceptions of supports and barriers, future research should include other HBCUs and predominately White institutions (PWIs).

References

Brown, S. D., & Krane, N. E. R. (2000). *Four (or five) sessions and a cloud of dust: Old assumptions and new observations about career counseling.* In S. D. Brown & R. W. Lent (Eds.), *Handbook of counseling psychology* (pp. 740–766). John Wiley & Sons, Inc.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39, 175–91. DOI: 10.3758/BF03193146.

Fouad, N. A., & Bingham, R. P. (1995). *Career counseling with racial and ethnic minorities. Handbook of vocational psychology: Theory, research, and practice* (2nd ed., pp. 331–365). Mahwah, NJ: Lawrence Erlbaum Associates.

Gysbers, N. C., Heppner, M. J., & Johnston, J. A. (2014). *Career counseling: Holism, diversity, and strengths*. John Wiley & Sons.

Lent, R. W., Brown, S. D., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models. *Journal of Counseling Psychology*, 50(4), 458–65. DOI: 10.1037/0022-0167.50. 4.458.

Lent, R. W., Sheu, H. B., Schmidt, J., Brenner, B., Wilkins, G., Brown, S. D., Gloster, C. S., Schmidt, L. C., Lyons, H., & Treistman, D. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically Black universities. *Journal of Counseling Psychology*, 52(1), 84–92. DOI: 10.1037/0022-0167.52.1.84.

National Student Clearinghouse Research Center. (2017). *Persistence and retention-2017: National, persistence, postsecondary, snapshot report.* Retrieved from https://nscresearchcenter.org/wp-content/uploads/SnapshotReport28a.pdf

National Science Foundation, National Center for Science and Engineering Statistics. (2016). *Women, minorities, and persons with disabilities in science and engineering: 2016.* Special Report NSF 15-311. Arlington, VA. Retrieved from http://www.nsf.gov/statistics/wmpd/.

Sharf, R. S. (2016). *Applying career development theory to counseling*. Cengage Learning

Worthington, R. L., Mobley, M., Franks, R. P., & Tan, J. A. (2000). Multicultural counseling competencies: Verbal content, counselor attributions, and social desirability. *Journal of Counseling Psychology*, 47(4), 460–8. DOI: 10.1037/0022-0167.47.4.460.

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The Impact of Religious Identity on the Efficacy of Evolution Instruction with Cultural Competence

Rahmi Aini, Alexa Summersill, Casey Epting (Middle Tennessee State University), Baylee Edwards, Sara Brownell (Arizona State University), & Elizabeth Barnes (Middle Tennessee State University)

Background and significance Evolution is a key concept of biology, yet many undergraduate biology students still reject it (AAAS., 2011; Brownell et al., 2014). The majority of undergraduate biology students are religiously affiliated (Southerland & Scharmann, 2013), and the perceived conflict between religion and evolution is known to play a significant role in their acceptance of evolution (Barnes et al., 2021; Dunk et al., 2017). However, most instructors teaching evolution are not religious (Ecklund & Scheitle, 2007), and some hold biases against religious students (Barnes, Truong, et al., 2020; Scheitle & Corcoran, 2021). Possible reasons for the perceived conflict among biology students include a lack of Christian biologists teaching evolution and a lack of culturally competent instruction for religious students by non-religious instructors teaching evolution.

Religious Cultural Competence in Evolution Education (ReCCEE) has been recommended to bridge the gap between religious conflicts and evolution instruction (Barnes & Brownell, 2017). ReCCEE includes practices such as acknowledging student autonomy over their religious beliefs, highlighting the spectrum of religious beliefs and their compatibility with evolution, presenting the bounded nature of science, providing role models of religious scientists who accept evolution, and explicitly stating the potential compatibility between religion and evolution. Studies show that students can reduce conflict when non-religious instructors provide religious scientist role models who accept evolution and discuss the nature of science as agnostic rather than atheistic (Barnes et al., 2020; Truong et al., 2018). Integrating religious instructors who discuss the compatibility of evolution and religion can also increase students' acceptance of evolution (Ferguson & Jensen, 2021). However, it is unclear if instructors' and students' religious identities moderate the effectiveness of religious cultural competence. This study aimed to determine the degree to which religious cultural competence can increase students' acceptance of evolution, increase perceived compatibility between religion and evolution, and reduce perceived conflict between evolution and religion in a randomized controlled trial study. Additionally, the study examined how the religious identity of instructors and students affected the efficacy of religious cultural competence.

Methods and Analyses In Fall 2022 and Spring 2023, 2,625 students from 19 undergraduate biology courses in 11 states participated in this study. The students were randomly assigned to three conditions where they watched a video with facts about evolution only (*Condition 1, n*=891), or with ReCCEE where an instructor revealed themselves as not religious (*Condition 2, n*=863), or with ReCCEE where the same instructor revealed themselves as Christian (*Condition 3, n*=871). Participants completed a survey before and after watching the video to measure their perceptions of conflict and compatibility between evolution and religion. They also completed surveys on general evolution acceptance and human evolution acceptance. Linear mixed models were used to analyze the effects of cultural competence conditions, religious affiliation, and instructor identity on participants' responses.

FINDINGS

Does religious cultural competence in evolution instruction lead to better student outcomes than evolution instruction without religious cultural competence? After the intervention, students who received cultural competence were more likely to increase their acceptance of human evolution, perceive greater compatibility, and experience less conflict between evolution and religion compared to the control group (Figure 1). Cultural competence had significant main effects, showing higher acceptance of human evolution ($b=0.04$, $p < 0.5$), perceived compatibility ($b=0.18$, $p < 0.001$), and less perceived conflict ($b=-0.37$, $p < 0.001$) after the intervention.

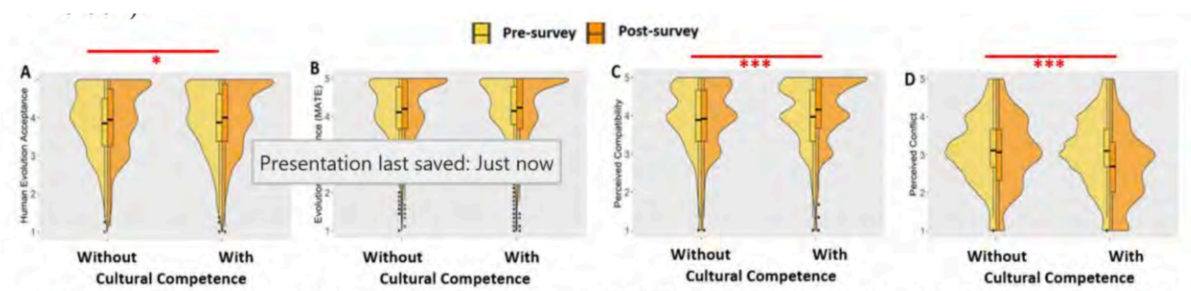

Figure 1: Distribution and average of the measurement in different conditions before and after instruction. Higher scores indicate greater acceptance and perceived compatibility or conflict. The cross bars represent mean scores.

Does an instructor revealing a secular or religious identity impact the effectiveness of religious cultural competence in evolution education? All student groups had positive outcomes after receiving evolution instruction with cultural competence from both a Christian and non-religious instructor (Fig 3). Atheist students showed greater increases in acceptance of human evolution and perceived compatibility when the instructor identified as non-religious (Fig 2A and 2C). The interaction between instructor and student identity did not significantly predict acceptance of human evolution, but it did significantly predict perceived compatibility for atheist students ($b=0.33$, $p<0.01$). The interaction between instructor and student religious identity was also not significant in predicting change in perceived conflict, indicating that cultural competence reduced students' perceived conflict with evolution regardless of student or instructor identity.

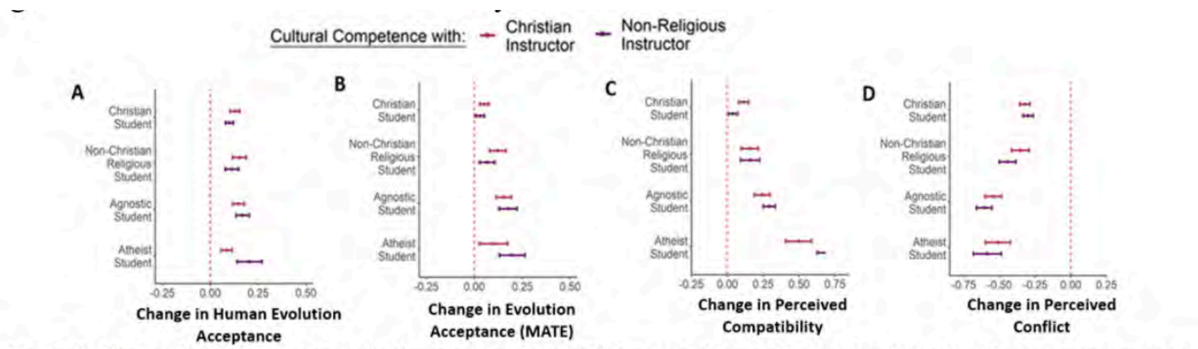

Figure 2: Change in students' scores of all measurements in different conditions of instructors' identity. The bar represents the standard deviation, and the point represents the mean. A higher score indicates a gain after the instruction.

General discussion and implications This study is the first to demonstrate the effect of religious cultural competence across many classes using a randomized controlled trial. Additionally, we found that cultural competence will reduce students' perceived conflict between evolution and religion, and regardless of instructors' religious identity, it can positively impact students' acceptance of evolution. Interestingly, we found that non-religious instructors are particularly effective in reducing conflict among secular biology students. One limitation of the study was the lack of a condition where cultural competence was used without the instructor revealing a religious or non-religious identity. Future research could explore the effects of ReCCEE when an instructor does not reveal a religious or non-religious identity and if this is better for outcomes of students from different religious and non-religious backgrounds.

References

American Association for the Advancement of Science. (2011). *Vision and Change in Undergraduate Biology Education*. https://visionandchange.org/finalreport/

Barnes, M. E., & Brownell, S. E. (2017). A call to use cultural competence when teaching evolution to religious college students: Introducing religious cultural competence in evolution education). *CBE—Life Sciences Education*, *16*(4), es4. https://doi.org/10.1187/cbe.17-04-0062

Barnes, M. E., Dunlop, H. M., Sinatra, G. M., Hendrix, T. M., Zheng, Y., & Brownell, S. E. (2020). "Accepting Evolution Means You Can't Believe in God": Atheistic Perceptions of Evolution among College Biology Students. *CBE—Life Sciences Education*, *19*(2), ar21. https://doi.org/10.1187/cbe.19-05-0106

Barnes, M. E., Supriya, K., Zheng, Y., Roberts, J. A., & Brownell, S. E. (2021). A New Measure of Students' Perceived Conflict between Evolution and Religion (PCoRE) Is a Stronger Predictor of Evolution Acceptance than Understanding or Religiosity. *CBE—Life Sciences Education*, *20*(3), ar42. https://doi.org/10.1187/cbe.21-02-0024

Barnes, M. E., Truong, J. M., Grunspan, D. Z., & Brownell, S. E. (2020). Are scientists biased against Christians? Exploring real and perceived bias against Christians in academic biology. *PLOS ONE*, *15*(1), e0226826. https://doi.org/10.1371/journal.pone.0226826

Brownell, S. E., Freeman, S., Wenderoth, M. P., & Crowe, A. J. (2014). BioCore Guide: A Tool for Interpreting the Core Concepts of Vision and Change for Biology Majors. *CBE—Life Sciences Education*, *13*(2), 200–211. https://doi.org/10.1187/cbe.13-12-0233

Dunk, R. D. P., Petto, A. J., Wiles, J. R., & Campbell, B. C. (2017). A multifactorial analysis of acceptance of evolution. *Evolution: Education and Outreach*, *10*(1), 4. https://doi.org/10.1186/s12052-017-0068-0

Ecklund, E. H., & Scheitle, C. P. (2007). Religion among Academic Scientists: Distinctions, Disciplines, and Demographics. *Social Problems*, *54*(2), 289–307. https://doi.org/10.1525/sp.2007.54.2.289

Ferguson, D. G., & Jensen, J. L. (2021). Role models, compatibility, and knowledge lead to increased evolution acceptance. *Evolution: Education and Outreach*, *14*(1), 16. https://doi.org/10.1186/s12052-021-00155-x

Scheitle, C. P., & Corcoran, K. E. (2021). Endorsement of Religion–Science Conflict as an Expression of Group Solidarity among Graduate Students in the Sciences. *Sociology of Religion*, *srab003*. https://doi.org/10.1093/socrel/srab003

Truong, J. M., Barnes, M. E., & Brownell, S. E. (2018). Can Six Minutes of Culturally Competent Evolution Education Reduce Students' Level of Perceived Conflict Between Evolution and Religion? *The American Biology Teacher*, *80*(2), 106–115. https://doi.org/10.1525/abt.2018.80.2.106

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Examining Relationships Between Secondary Teachers' Content Knowledge and Attitudinal Traits

Christopher Bonnesen, Jeremy Strayer (Middle Tennessee State University), Andrew Ross (Eastern Michigan University), & Yvonne Lai (University of Nebraska-Lincoln)

Background For decades, secondary mathematics education has lived within a narrative of disconnect. A century ago, Klein (1924/1932, as cited in Kilpatrick, 2019) lamented the "discontinuity" between undergraduate mathematics experiences and secondary teaching. Empirical findings have documented that many secondary teachers find their undergraduate mathematics courses irrelevant to their teaching (Goulding et al., 2003; Zazkis & Leikin, 2010). The context for this study is the MODULE(S^2) project, a research and development effort that produced written curricular materials in algebra, geometry, mathematical modeling, and statistics. Materials for each content area are intended to span one term of a university mathematics course for prospective secondary mathematics teachers (PSMTs). All materials feature opportunities for PSMTs to apply course content to teaching situations such as responding to student ideas, thus addressing the discontinuity between university mathematics and secondary teaching practice as discussed above. In a previous study, the MODULE(S^2) project used pre- and post-term data to examine relationships between PSMTs' confidence in their ability to teach certain concepts (i.e., expectancy), their content knowledge for teaching (CKT) those concepts, and the extent to which they value certain evidence-based teaching practices. That research found mean increases in PSMTs' outcomes across each of these constructs (Lai et al., 2023). Further, the prior study indicated that PSMTs' instructors' enactment of evidence-based practices had a non-negligible impact on a subset of these constructs.

Current Study In the present study, we build on prior results by considering the association between CKT and expectancy or value. We define content knowledge for teaching (CKT) as disciplinary knowledge entailed in the recurrent work of teaching mathematics or statistics (Ball et al., 2008; Baumert et al., 2010; Thompson & Thompson, 1996). With respect to attitudinal traits, we focus on expectancy for teaching key concepts and value for enacting evidence-based teaching practices when doing so. Expectancy is a PSMTs' expectation of success at teaching the concept (Wigfield & Eccles, 2000). Value is the importance of enacting certain teaching practices well, and can encompass utility, enjoyment, and personal fulfillment (Eccles & Wigfield, 2020). This study seeks an answer to the research question: **To what degree do PSMTs' gains in content knowledge for teaching associate with gains in expectancy and value?**

Data & Methodology All participating PSMTs were enrolled in courses using MODULE(S^2) curricula, which promotes explicit links between university course content and secondary mathematics teaching practice. Participants were 137 PSMTs, with 50 in algebra, 25 in geometry, 16 in mathematical modeling, and 46 in statistics. As for instrumentation, we measured pre-/post-term expectancy and value for carrying out evidence-based practices using a Likert-item survey whose phrasings were drawn from Wigfield and Eccles (2000) and was shown to have met typical standards for internal reliability in our previous study (Lai et al., 2023). We measured CKT in each area using instruments featuring applications of the specified content to teaching (see Lai et al., 2023 for more details on instrument validity for capturing PSMTs' CKT). The first three authors analyzed relationships between PSMTs' expectancy, value, and CKT using Pearson's correlation coefficient *r* to measure effect size of correlations. We used *p*-values to determine evidence of a non-zero correlation in the theoretical population, but we focus on practical significance in our conclusions here.

Preliminary Results The Pearson's correlation coefficients *r* and *p*-values reported in Table 1 show the relationships between PSMTs' gains in CKT versus their gains in expectation to implement and valuation of core instructional practices. Each PMST's scores on these metrics were first converted to a percent change from pre to post out of total possible points on the relevant assessment or survey. Additionally, Figure 1 is partitioned by content area as well as the whole group. Note that results for the combined group were statistically significant with $p < 0.05$, though their *r* values were small. The only content-specific significant result was for statistics and value, with a higher *r* value of +0.41.

	CKT vs. E *r*-value	CKT vs. E *p*-value	CKT vs. V *r*-value	CKT vs. V *p*-value
Algebra	+0.107	0.458	+0.022	0.882
Geometry	+0.137	0.514	+0.153	0.466
Modeling	+0.342	0.195	+0.336	0.203
Statistics	+0.188	0.212	+0.41	0.005
All Content Areas Combined	+0.168	0.0497	+0.199	0.019

Figure 1. Pearson's correlation coefficient r and the p-value for correlations between PSMT's gains in content knowledge for teaching (CKT) and gains in expectancy (E) or value (V). Statistically significant results are highlighted in green.

Discussion The pre/post-gains in PSMTs' expectancy, value, and CKT found mostly insignificant correlations between PSMTs' gains in these aspects, with some exceptions. These results imply that PSMTs' expectation and valuation of core instructional practices may not be associated with their learning of mathematics content for teaching, with a potential exception of the statistics content area. It is important to note that our work in this area is still in the initial phase. Additional efforts will investigate associations between other variables such as post CKT scores versus post expectancy/value scores, rather than focusing on gains.

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References

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5), 389-407.

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., Klusmann, U., Krauss, S., Neubrand, M., & Tsai, Y. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, 47(1), 133–180.

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology*, 61, 101859.

Goulding, M., Hatch, G., & Rodd, M. (2003). Undergraduate mathematics experience: Its significance in secondary mathematics teacher preparation. *Journal of Mathematics Teacher Education*, 6, 361-393.

Kilpatrick, J. (2019). A double discontinuity and a triple approach: Felix Klein's perspective on mathematics teacher education. *The legacy of Felix Klein, ICME-13 Monographs*, 215-225.

Lai, Y., Strayer, J. F., Ross, A., Adamoah, K., Anhalt, C. O., Bonnesen, C., Casey, S., Kohler, B., & Lischka, A. E. (2023). Enhancing prospective secondary teachers' potential competence for enacting core teaching practices—through experiences in university mathematics and statistics courses. *ZDM–Mathematics Education*, 1-15.

Thompson, A. G., & Thompson, P. W. (1996). Talking about rates conceptually, Part II: Mathematical knowledge for teaching. *Journal for Research in Mathematics Education*, 27(1), 2-24.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of motivation. *Contemporary Educational Psychology*, 25, 68–81.

Zazkis, R., & Leikin, R. (2010). Advanced mathematical knowledge in teaching practice: Perceptions of secondary mathematics teachers. *Mathematical Thinking and Learning*, 12(4), 263-281.

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Student Perceptions of Individual and Group Creativity in Proving

Amanda Lake Heath (Middle Tennessee State University)

Abstract Both collaboration and creativity are central to the work of mathematicians (Karakok et al., 2015; Sriraman, 2004). Professional mathematicians have indicated collaboration is an important feature of their work (Sriraman, 2004), and the Conference Board of Mathematical Sciences (2016) has called for university mathematics classrooms to incorporate more active, collaborative learning. Therefore, there is a substantial need for K-16 education to focus on developing creative mathematicians and problem solvers with strong communication and collaboration abilities. In mathematics, students follow a journey in which there is an eventual transition from computational to proof-based mathematics (Civian & Schley, 1996). During this transition to proof, students are often expected to become producers of mathematical ideas on their own for perhaps the first time (Boyle et al., 2015). For this reason, it is critical to study mathematical creativity and collaboration within the context of undergraduate mathematics courses and proof in order to cultivate the expertise needed by future mathematicians.

The purpose of this study is to investigate the creativity at work during collaborative proving. In this presentation, I will address the research question: **What actions or moments of the collaborative proving process do individuals report fostered their creativity?**

Definitions and Theoretical Framing In this study, I use the phrase mathematical creativity to describe the processes of creating, constructing, or implementing mathematical ideas, strategies, or processes, which are perceived as non-routine by the individual. Moreover, I use the term ***collaborative creativity in proving*** to describe the process of approaching a shared goal in proving with significant contributions from two or more people, in which the proving task is either (a) assumed to be non-routine for all group members based on context or (b) established to be non-routine for all group members by asking them for their perspective. Residue Taking mathematical creativity as a relative construct requires asking students what they recall as fostering creativity for them, and these recollections will describe "what actually comes to the fore of [students'] attention" (Marton et al., 2004) about their creativity during collaborative proving.

Residue provides a way for thinking about what students take with them from classroom experiences. Therefore, residue can give insight into the experiences, activities, and interactions that were meaningful for the student and inform how instructors can best shape classroom environments and activities to foster collaborative creativity in proving.

Background It is generally accepted that mathematical creativity can be developed and enhanced in students (Sriraman & Haavold, 2017; Zazkis & Holton, 2009), and mathematicians believe that mathematical creativity can and should be fostered in undergraduate mathematics courses (Karakok et al., 2015). Despite this consensus, there is little empirical research on what teaching strategies develop mathematical creativity among undergraduate students (Savic et al., 2022).

In extant literature, the teacher actions most supported as effectively promoting mathematical creativity are choosing appropriate tasks, allowing time for incubation, demonstrating different ways to solve problems and illustrating the mathematical process for students), making the classroom a safe place to take risks, attending to the emotions of students , and providing space for discussion and disagreement (Satyam et al., 2022; Savic, El Turkey, et al., 2017a, 2017b; Tang et al., 2022). No extant research has explicitly considered the impact collaborative work or collaborative proving may have on creativity. Moreover, investigating student perceptions of how collaborating with their peers on proving tasks fosters (or does not foster) creativity for them can inform how to best facilitate collaborative activities to promote creativity in proving.

Methods

Context and Participants Data was collected from an undergraduate Introduction-to-Proof course at a large public southeastern university in the United States. This course was facilitated in a collaborative, inquiry-based learning environment in which small groups of students worked together to prove instructor-provided mathematical conjectures. This report focuses on undergraduate students' impressions of their creativity after working in groups in class to collaboratively prove the statement: *The product of consecutive twin primes is one less than a perfect square.*

Data Collection and Analysis After an in-class collaborative proving activity, students completed a retrospective writing assignment in which they were tasked with reflecting upon their experience working collaboratively in class and describing the times in which they felt (or did not feel) creative during the activity. Students were asked to answer the question "When during the collaboration did you feel like you or your group were creative? If you did not feel creative, explain why not. Include as many details as you can."

First, I conducted an inductive, in-vivo coding strategy (Saldaña, 2016). The in-vivo codes were grouped into themes, and I conducted a second round of coding using this list of themes to identify the most frequently cited moments and incidents that initiated creativity for students. All sentences of the responses containing reasons for feeling (or not feeling) creative were given at least one thematic code.

Results The inductive analysis of participant retrospective writing assignment submissions revealed 11 themes in their reflection on their individual creativity: Brainstorming, mistakes, noticing patterns/making conjectures, task novelty, suspense/pressure, teamwork, trying different ways/seeing things in different ways, writing an equation/formula, connecting mathematics and words, uncreative, and other. The most common themes were teamwork/collaboration, noticing patterns/making conjectures, uncreative, and writing an equation. More details regarding the thematics categories and there prevalence will be reported in the conference presentation.

Discussion and Conclusion In this study, I have characterized the types of actions or moments students reported as causing them to feel creative during an in-class collaborative proving exercise. A first observation is that students rarely emphasized themselves as feeling individually creative in their narratives (e.g., "I felt creative when…"), but rather emphasized the creative actions of the group as a whole (e.g., "my group was creative when…"). This distinction, in part, may be attributed to feeling as though the group's capacity for acting creatively was greater than capacity of the sum of the constituent members, as one participant indicated, "I believe that my group was even more creative than we could have been individually." Further, students may feel uncomfortable taking individual ownership in their narrative writing reflecting upon a collaborative task.

My preliminary findings indicate students may recognize opportunities to be creative in mathematical proving by collaborating with their peers in specific ways. The results of this study may be able to both verify the results from previous research on student perceptions of creativity in Calculus I (Satyam et al., 2022; Cilli-Turner et al., 2023) as applicable also to an Introduction-to-Proof setting, but also provide a guide for facilitating creativity-fostering collaborative work in undergraduate proof-based mathematics courses.

References

Boyle, J. D., Bleiler, S. K., Yee, S. P., & Ko, Y. Y. (2015). Transforming perceptions of proof: A four-part instructional sequence. *Mathematics Teacher Educator, 4*(1), 32–70. https://doi.org/10.5951/mathteaceduc.4.1.0032

Cilli-Turner, E., Satyam, V. R., Savić, M., Tang, G., El Turkey, H., & Karakok, G. (2023). Broadening views of mathematical creativity: Inclusion of the undergraduate student perspective. J*ournal of Creativity, 33(*1), 100036.

Civian, J., & Schley, S. (1996). *Pathways for women in the sciences II: Retention in math and science at the college level.* Annual Meeting of the American Educational Research Association.
Conference Board of the Mathematical Sciences. (2016). *Active learning in post-secondary mathematics education.*https://www.cbmsweb.org/wp-content/uploads/2016/07/active_learning_statement.pdf

Karakok, G., Savic, M., Tang, G., & El Turkey, H. (2015). Mathematicians' views on undergraduate students' creativity. In K. Krainer & N. Vondrová (Eds.), N*inth congress of the European society for research in mathematics education (*pp. 1003–1009). ERME. ttps://hal.archives-ouvertes.fr/hal-01287301

Marton, F., Tsui, A. B. M., Chik, P. P. M., Ko, P. Y., & Lo, M. L. (2004). *Classroom discourse and the space of learning*. Routledge. https://doi.org/10.4324/9781410609762

Saldaña, J. (2016). T*he coding manual for qualitative researchers.* SAGE.

Satyam, V. R., Savic, M., Cilli-Turner, E., El Turkey, H., & Karakok, G. (2022). Exploring the role of students' views of creativity on feeling creative. *International Journal of Mathematical Education in Science and Technology*, *53*(1), 151–164. https://doi.org/10.1080/0020739X.2021.1961032

Savic, M., El Turkey, H., Tang, G., Karakok, G., Cilli-Turner, E., Plaxco, D., & Omar, M. (2017a). Pedagogical practices for fostering mathematical creativity in proof-based courses: Three case studies. In A. Weinberg, C. Rasmussen, J. Rabin, M. Wawro, & S. Brown (Eds.), *Proceedings of the 20th Annual Conference on Research in Undergraduate Mathematics Education*.

Savic, M., El Turkey, H., Tang, G., Karakok, G., Cilli-Turner, E., Plaxco, D., & Omar, M. (2017b). Pedagogical practices that foster mathematical creativity at tertiary-level proof-based courses. In D. Pitta-Pantazi (Ed.), *Proceedings of the 10th International Mathematical Creativity and Giftedness Conference*. Department of Education, University of Cyprus.

Savic, M., Satyam, V. R., Turkey, H. E., & Tang, G. (2022). Mathematical creativity at the tertiary level: A systematic review of the literature. In *Mathematical Creativity* (pp. 105–120). Springer.

Sriraman, B. (2004). The characteristics of mathematical creativity. *The Mathematics Educator*, *14*(1), 19–34. https://doi.org/10.1007/s11858-008-0114-z

Sriraman, B., & Haavold, P. (2017). Creativity and giftedness in mathematics education: A pragmatic view. In J. Cai (Ed.), *First compendium for research in mathematics education* (pp. 908–916). National Council of Teachers of Mathematics. https://doi.org/10.1007/BF00553919

Tang, G., Savic, M., Satyam, V. R., El Turkey, H., & Karakok, G. (2022). “The reason why I didn’t like [math] before is because I never felt creative”: Affective outcomes from teaching actions to foster mathematical creativity in Calculus 1. In S. S. Karunakaran & A. Higgins (Eds.), *Proceedings of the 24th Annual Conference on Research in Undergraduate Mathematics Education*.

Zazkis, R., & Holton, D. (2009). Snapshots of creativity in undergraduate mathematics education. In R. Leikin, A. Berman, & B. Koichu (Eds.), *Creativity in mathematics and the education of gifted students* (pp. 345–365). Sense. https://doi.org/10.1163/9789087909352_022

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Who Wrote it Better? A Comparison of AI and Teacher Created Lessons for High School Mathematics

Emily McDonald (Hamilton County Schools & University of Tennessee – Knoxville)

Abstract In the modern era of education, teachers face numerous responsibilities and competing demands that go beyond traditional classroom instruction. The role of educators encompasses not only planning and delivering lessons but also nurturing students' social, emotional, and belonging-related needs. As educational technology continues to advance, Machine Learning (ML) and Artificial Intelligence (AI) have emerged as potential game-changers in the field of education (Alam, 2021). Some argue that these technologies can augment or even replace certain aspects of teachers' tasks, leading to significant transformations in the education landscape (Bates et al., 2020).

This proposed presentation will focus on the lesson creation capabilities of popular AI websites in comparison to teacher created lessons. This comparative analysis will utilize a few teacher created lessons and AI created lessons based on the same topic in a high school mathematics course. Lesson characteristics that will be compared are alignment to state content standards, engagement components or activities, rigor, differentiation, creation time, etc. All lessons will be reviewed based on a rubric to better compare and share the findings.

High school math teachers will be recruited from Hamilton County Schools to create and submit a lesson plan that is aligned to the Tennessee State Math Standards. The AI tools that will be used for lesson plan creation are ChatGPT, Google Bard, LessonPlans AI, and other text-based AI tools.

Background The integration of ML and AI in education has sparked debates and discussions within academic circles and policymaking bodies (Selwyn, 2019). As the promise of AI in education becomes more apparent, it is crucial to critically examine the extent to which these technologies can supplement or replace a teacher's responsibility.

The application of ML and AI in education has witnessed a significant evolution in recent years. The adoption of digital technologies and the availability of large datasets have enabled the development of AI-driven educational tools and platforms (Murphy, 2019). Early implementations of AI in education primarily focused on adaptive learning systems that personalize educational content based on individual student performance. As technology advances, AI has found applications in automated grading and assessment, intelligent tutoring systems, and learning analytics, providing valuable insights into student learning patterns and progress (Popenici & Kerr, 2017). Also, AI-powered chatbots and virtual assistants have emerged to facilitate student engagement and support.

Debates surrounding the potential augmentation and replacement of teachers' tasks by AI technologies have generated varying opinions within the education community. Proponents argue that AI can enhance teaching efficiency and effectiveness by automating routine administrative tasks, enabling teachers to focus on individualized instruction and fostering student-teacher relationships (Lameras & Arnab, 2021). A study by Mavrikis et al. (2019) found that teachers who used AI-driven analytics reported increased awareness of students' learning difficulties, enabling targeted support.

However, critics express concerns about the ethical implications of AI in education. They highlight the risk of overreliance on technology, which may lead to reduced human interaction and limit the development of critical social and emotional skills in students (Lameras & Arnab, 2021). Furthermore, fears of job reductions among educators have been raised, with some suggesting that AI could potentially replace teachers altogether, thereby compromising the quality of education (Chan & Tsi, 2023).

The integration of ML and AI in education holds immense potential to augment and enhance various aspects of teachers' responsibilities. Through personalized learning, adaptive feedback, and data-driven insights, AI can revolutionize the teaching and learning process, optimizing student outcomes and promoting individualized education. However, it is crucial to strike a delicate balance between AI augmentation and preserving the indispensable human touch in education.

References:

Alam, A. (2021). Possibilities and apprehensions in the landscape of artificial intelligence in education. In 2021 International Conference on Computational Intelligence and Computing Applications (ICCICA) (pp. 1-8). IEEE.

Bates, T., Cobo, C., Mariño, O., & Wheeler, S. (2020). Can artificial intelligence transform higher education. International Journal of Educational Technology in Higher Education, 17(1), 1-12.

Chan, C. K. Y., & Tsi, L. H. (2023). The AI Revolution in Education: Will AI Replace or Assist Teachers in Higher Education?. arXiv preprint arXiv:2305.01185.

Lameras, P., & Arnab, S. (2021). Power to the teachers: an exploratory review on artificial intelligence in education. Information, 13(1), 14.

Mavrikis, M., Geraniou, E., Gutierrez Santos, S., & Poulovassilis, A. (2019). Intelligent analysis and data visualization for teacher assistance tools: The case of exploratory learning. British Journal of Educational Technology, 50(6), 2920-2942.

Murphy, R. F. (2019). Artificial intelligence applications to support K-12 teachers and teaching. Rand Corporation, 10.

Popenici, S. A., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. Research and Practice in Technology Enhanced Learning, 12(1), 1-13.

Selwyn, N. (2019). Should robots replace teachers?: AI and the future of education. John Wiley & Sons.

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Assessing the Programming Self-Efficacy of Teachers through Professional Development Combining Drones and STEM Activities

Deborah McAllister (University of Tennessee – Chattanooga)

Overview of the Background Literature Goodnough et al. (2019) collected data regarding teacher pedagogical content knowledge while presenting a unit using drones to study animal habitats. Results showed that self-efficacy levels and understanding of student learning were enhanced through this experience, which, then, translated to increased pedagogical content knowledge and changes in how the teachers planned to conduct their classrooms. Teacher self efficacy was strengthened as teachers created inquiry-based, classroom environments to engage learners in science.

Walach and Harrell (2021) provided a brief overview of the increasing popularity of drones. They detailed a teacher training workshop to help engineering and technology teachers prepare to use drones in their classrooms. Participants learned to fly in an open space, learned how the drones were built, and modified their drones with more complex electronics. Participants reported a positive experience with the program.

Balogun and Miller (2022) developed, and pilot-tested, a drone club model for out-of-school STEM learning and career pathway exploration for middle and high school students. The activities were primarily related to national security/defense or complex manufacturing. The main goals of the program were to provide students with experience in a new technology, inform students about relevant fields to the technology, and provide students with skills that would be attractive to potential employers. K-12 educators and subject-matter experts provided feedback for revision. Feedback topics ranged from safety to instruction to assessment.

Bartholomew et al. (2018) provided reasons why quadcopter drones could be useful for teaching computational thinking, programming, coding, and analytical thinking. They offered a description of one of the activities they conducted, in which drones were used to transport items in a simulation of a mountain rescue. They included comprehensive lesson plans, with relevant standards identified.

Talley (2023) reported on an all-girl, middle grades, drone club preparing to compete in a championship. Girls reported interests in flying and programming, and solving problems such as recuing an animal with a drone. The emphasis was on learning for a future career in a STEM discipline.

Tsai et al. (2019) developed a 16-item, computer programming self-efficacy scale for students above the middle grades level. They reported a reliability alpha of .96 for the self-efficacy scale and a range of .84 to .96 for the subscales. The five subscales include Logical Thinking, Cooperation, Algorithm, Control, and Debug. The subscales were defined on p. 1349- 1350 as the following:

• Logical Thinking "measures students' perceptions of their ability to write a program using logical conditions."

• Cooperation “evaluates students’ perceptions of the cooperative nature of a programming task.”
• Algorithm “measures students’ perceptions of their ability to build up an algorithm for solving a problem independently while programming.”

• Control “assesses students’ perceptions about their ability to control over a program editor.”

• Debug “measures students’ perceptions of their ability to correct program errors.”

Significance of the Research As programming tasks are becoming more commonplace in K-12 classrooms, this program focused on work with pre-service and in-service teachers as they, as teachers, provide experiences to improve the programming and other technological skills of their students. Teachers learned to program and fly the DJI (2023b) Tello EDU drone, which can be programmed to fly automatically using an app, or can be flown manually, either by using an app or a physical game controller. The DroneBlocks App (DroneBlocks, n.d.) was used for flying through drag-and-drop, block coding, and the DJI (2023a) Tello App was used for flying manually. Each teacher self-evaluated knowledge and skills, before and after a multi-day workshop. The program was presented twice, as a 4-day, summer workshop in the summer of 2022, and as a 2-day workshop on consecutive Saturdays in the winter of 2023.

Research Questions The goal was to provide high-quality, teacher professional development to increase knowledge and instructional skills for integrating drones into the elementary, middle grades, and secondary classroom. Measurable objectives included the following:

1. There will be a statistically significant increase in teachers’ scores on a 16-item, computer programming self-efficacy survey, between administrations of the instrument.

2. There will be a statistically significant increase in teachers’ scores on the five subscales of the computer programming self-efficacy survey, between administrations of the instrument.

3. Responses to open-ended questions will be analyzed for trends.

Data Analysis Procedures Participants completed the 16-item, computer programming self-efficacy scale, a 6-point, Likert scale (Tsai et al., 2019), at the beginning of the first day and the end of the last day of the workshop. The scale contains five subscales of three or four items considered as a subscale grouping. The five subscales of the instrument include Logical Thinking, Cooperation, Algorithm, Control, and Debug. Participants responded to three, open-ended questions:

1. List 3 things that were learned through this activity.

2. How will you use one or more of these activities in an educational setting?

3. What are some areas for workshop improvement?

Summary of Findings The results of the Tsai et al. (2019) survey were analyzed separately for the two workshops, as there was a difference in the length of time the participants attended the professional development sessions. With a 6-point scale, the possible range of scores was 6 to 96. For the summer 2022 workshop, the pre-test range was 34 to 90 and the posttest range was 85 to 91. For the winter 2023 workshop, the pre-test range was 30 to 80 and the post-test range was 65 to 95. Results of t tests showed a significant increase in computer programming self-efficacy and significant increases in all subscale scores for both workshops. Word clouds were generated to display the results of the three, open-ended questions.

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Digital Agriculture Summer Camp and Non-formal Learning: A Comparative Analysis of the First and Second Year Camp Participant Knowledge and Postsecondary STEM Interests

Carly Altman, Chaney Mosley, & Song Cui (Middle Tennessee State University)

Introduction and Literature Review Science, technology, engineering, and math (STEM) education has provided interdisciplinary connections to agriculture, food and natural resources (AFNR) education unlike other content areas or pedagogical approaches (Wang & Knobloch, 2020). Therefore, growth in STEM and AFNR education brings possibilities for a variety of instructional approaches and inquiry, including non-formal learning. Non-formal learning encompasses out-of-school educational experiences, and may include after-school club activities, summer camps, instrument lessons, scouting, and other opportunities (Sefton-Green, 2012). Non-formal education has no official forms or structures, it can be any type of intentional or systematic activity which may be adapted to fit the purpose of the learning (Manolescu et al., 2018).

While any educational approach should be informed by evidence-based practices, "research on integrating STEM and AFNR has not kept pace with the educational reform" (Wang & Knobloch, 2018, p. 259). As a way to integrate these two fields, a three-week interdisciplinary digital agriculture summer camp was held for high school students to increase both knowledge and postsecondary interests in three areas: (a) precision agriculture; (b) drone technology; and (c) data science. Short-term educational camps can have a positive impact on students, including their learning achievements (Foster & Shiel-Rolle, 2011); however, a search for empirical studies regarding agriculture-based STEM camps yielded zero results. To date, there are been two session of the digital agriculture summer camp.

The purpose of this study was to investigate the impact of participation in a non-formal digital agriculture summer camp for high school students on camper knowledge and postsecondary interests. This study was funded by USDA-NIFA award # 2021-67037-35972.

Research Questions The three focus areas of the camp under investigation were precision agriculture, drone technology, and data science. The research questions were:

1. How does participating in a digital agriculture summer camp impact camper knowledge of precision agriculture, drone technology, and data science?

2. How does participating in a digital agriculture summer camp impact camper interest in AFNR, aerospace, and data science postsecondary pursuits?

3. How do camp sessions (years 1 and 2) differ in terms of enhancing camper knowledge of interest in precision agriculture, drone technology, and data science?

Methodology At the conclusion of the camps, all participants completed a researcher-designed survey using five-point Likert scales for each content area identified in the research questions. A survey using a Likert scale employs a series of four or more Likert-type items that generate a composite score and, when combined, provide a quantitative measure of a trait (Boone & Boone, 2012). Demographic data were also collected. The survey utilized a retrospective pretest (or post-then-pre) design, in which the pretest is concurrently delivered with the posttest and participants are asked to recall knowledge before experiencing a program (Allen & Nimon, 2007).

The survey was organized into two sections with three scales in each section. Section one inquired about knowledge, asking how much campers knew before and after attending the camp with regard to precision agriculture, drone technology, and data science. The response options were: 1 = Very Little, 2 = Little, 3 = Some, 4 = Much; 5 = Very Much. Section two asked campers to indicate their level of agreement statements about postsecondary interest in AFNR, aerospace, and data science. The response options were: 1 = Strongly Disagree, 2 = Disagree, 3 = Uncertain, 4 = Agree, 5 = Strongly Agree.

Data Analysis and Results Survey data from Year 1 (N = 11) and Year 2 (N = 16) were analyzed and descriptive statistics were used to describe the sample. In Year 1, there were nine male participants and two females participants. Our participants included five Sophomores, one Junior, and five Seniors. In Year 2, there were 10 male participants and six female participants. Our participants included one Freshman, four Sophomores, five Juniors, and six Seniors.

Likert-scale data may be analyzed using *T*-tests (Boone & Boone, 2012). To answer research question one, in examining the differences between pre- and post-participation knowledge in each area of focus, paired samples *T*-tests were conducted. The significance level set for all tests was 0.05. For precision agriculture, results indicated a significant difference of knowledge pre- and post- participation, $t(26) = 14.61$, $p < .05$. For aerospace knowledge, results indicated a significant difference of knowledge pre- and post- participation, $t(26) = 21.65$, $p < 0$. For data science knowledge, indicated a significant difference of knowledge pre- and post- participation, $t(26) = 13.98$, $p < 0$. In Year 1, for all three areas of focus (agriculture, aerospace, and data science), there was an increase in knowledge (80%, 128%, and 96%, respectively). In Year 2, for all three areas of focus, there was an increase in knowledge (70% agriculture, 115% aerospace, and 47% data science, respectively). These results are similar to other university sponsored summer camps that have demonstrated knowledge improvement in math and robotics (Tichenor & Plavchan, 2010; van Delden & Yang, 2014).

For research question two, paired samples *T*-tests were conducted to examine the differences between pre- and post-participation interest in postsecondary pursuit for each area of focus. For precision agriculture, postsecondary pursuits, results indicated a significant difference pre- and post- participation, $t(26) = 4.53$, $p < 0$. For aerospace postsecondary pursuits, results indicated a significant difference pre- and post- participation, $t(26) = 3.44$, $p < .001$. For data science, postsecondary pursuits, results indicated a significant difference pre- and post- participation, $t(26) = 5.41$, $p < .05$. In Year 1, interest in related postsecondary education and careers changed (9%, 16%, 11%). In Year 2, interest changed (24%, 23%, 34%).

To answer research question 3, an independent samples *T*-test was conducted to compare post-participation knowledge of all areas of focus. For precision agriculture, between Year 1 (M = 3.39, SD =.82) and Year 2 (M = 3.56, SD = .43), results indicated there was no significant difference of enhanced knowledge about precision agriculture between the two years, t(25) = .63, *p* = .27. For aerospace, between Year 1 (*M* = 4.14, *SD* =.56) and Year 2 (*M* = 4.15, *SD* = .54), results indicated there was no significant difference of enhanced knowledge about aerospace between the two years, *t*(25) = -0.037, *p* = .49. For data science, between Year 1 (*M* = 2.89, *SD* =.55) and Year 2 (*M* = 3.84, *SD* = .81), results indicated there was a significant difference of enhanced knowledge about data science between the two years, *t*(25) = 3.37, *p* = 0.00122.

Conclusions and Recommendations The digital agriculture camp did increase knowledge and postsecondary interests. Prior experience of campers may impact knowledge enhancement between camp sessions. Future research should investigate differences between groups based on demographic data such as gender, race and ethnicity, ang grade level, among others.

References

Allen, J. M., & Nimon, K. (2007). Retrospective pretest: A practical technique for professional development evaluation. *Journal of Industrial Teacher Education, 44*(3), 27–42.

Boone Jr., H. N., & Boone, D. A. (2012). Analyzing Likert Data. *Journal of Extension, 50*(2), 30. https://doi.org/10.34068/joe.50.02.48

Manolescu T., Florea, N., & Arustei, C. (2018). Forms of learning within higher education. Blending formal, informal and non-formal. *Cross-Cultural Management Journal, 20*(1), 7–15.

Sefton-Green, J. (2012). Learning at not-school: A review of study, theory, and advocacy for education in non-formal settings (p. 100). The MIT Press. http://library.oapen.org/handle/20.500.12657/26062

Tichenor, M., & Plavchan, J. (2010). Summer camps: a fun way to reinforce math skills. *Journal of Instructional Psychology, 37*(1). https://link.gale.com/apps/doc/A224405381/AONE?u=tel_middleten&sid=googleScholar &xid=91be730a

van Delden, S., & Yang, K. P. (2014). Robotics summer camps as a recruiting tool: A case study. *Journal of Computing Sciences in Colleges, 29*(5), 14-22. https://dl.acm.org/doi/abs/10.5555/2600623.2600626

Wang, H. & Knobloch, N. (2020). Preservice educators' beliefs and practices of teaching STEM through agriculture, food, and natural resources. *Journal of Agricultural Education, 61*(2), 57-76. https://doi.org/10.5032/jae.2020.02057

Wang, H., & Knobloch, N. A. (2018). Levels of stem integration through agriculture, food, and natural resources. *Journal of Agricultural Education, 59*(3), 258-277 https://doi.org/10.5032/jae.2018.03258

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Enhancing STEM Learning Environments: Exploring Professional Development Opportunities in Workshops to Improve Students' Critical Thinking Skills

Gideon Eduah (Tennessee Technological University), Andrea Arce-Trigatti (Tallahassee Community College), & Ada Haynes (Tennessee Technological University)

Introduction To advance students' interest in STEM, faculty need to be resourced with the necessary skills to provide the best quality STEM education because faculty instructional strategies have direct influence on students (Avery & Reeve, 2013). There is a need for facilitators to evaluate the impact of professional development workshops on the faculty development in a period of increased demand for accountability and the urgency for improvement in teaching and learning in higher education (Light et al., 2009). These types of workshops are typically intended to help guide and support faculty as they navigate instructional pivots associated with student assessment and evaluation related to critical thinking skills as applied to their discipline. As high-quality professional development workshops, these are designed to focus on the core content and provide opportunities for faculty to be involved in active learning of advanced teaching strategies (DeMonte, 2013).

In this contribution, we feature two case studies regarding interdisciplinary faculty professional development workshops that integrated experiential learning strategies that led to the creation of active learning curricula focused on students' critical thinking skills in different science, technology, engineering, and mathematics (STEM) disciplines. Better understanding the integration of best practices in faculty development workshops is important to ensure that the quality and content of the material is shared in a way that leads to the largest gains in critical thinking. Additionally, identifying how these practices are interpreted by faculty is beneficial to developing a stronger partnership between facilitators and future opportunities.

Research Questions The following research questions guided this study: In what ways did faculty implement lessons learned from attending a professional development workshop focused on critical thinking?

Methodology and Timeline This study leverages a myriad of faculty artifacts collected as part of the critical thinking workshops that were implemented as professional development opportunities at different two-year and four-year institutions. Data includes an array of faculty active learning examples, Critical thinking Assessment Test Applications (CAT Apps), and finalized assignments that have been redesigned as part of the professional development process. The CAT was developed and refined with funding from the National Science Foundation (NSF) to assess students' critical thinking skills, serve as a model for better classroom assessments, and to provide faculty development opportunities (Haynes and Stein, 2020).

<u>Spring 2021 – Planning and Design</u> This study includes two types of faculty development workshops that were focused on the development of students' critical thinking skills through experiential learning strategies. Both workshop experiences were developed at different institutions and leveraged two different assessment strategies – one using the CAT and the other using the American Association of College and Universities' (AAC&U) Critical Thinking VALUE rubric (AAC&U, 2023). During the Spring 2021 semester, both workshops were

developed as experiential learning opportunities for faculty, with both being recruiting STEM faculty as part of an interdisciplinary professional development experience.

Summer 2021 -Fall 2022: Implementation and Data Collection Starting in the Summer 2021 semester, the different versions of the critical thinking workshops were implemented in a select number of institutions. Online versions were implemented across the country using the CAT, with an integration of STEM and interdisciplinary faculty representing both two- and four-year institutions. In terms of the AAC&U versions, both online and face-to-face implementation began in the Fall 2021 semester and continued in the Spring 2022 and Fall 2022 semesters with three different cohorts of STEM faculty members.

Spring 2023 - Analysis In the Spring 2023 semester, data from all implemented workshops from both versions of the professional development series that were implemented from the Summer 2021 semester to the Fall 2022 semester were organized and analyzed. Preliminary data analysis was intended to better understand what was working for these workshops and identify areas of improvement. As the analysis continued, thematic analysis regarding the various artifacts that were collected as part of this process commenced.

Data Analysis and Results Data collected from the workshops which are used as the analysis for this study include examples of experiential learning in both workshop contexts, faculty Critical thinking Assessment Test Applications (CAT Apps), and examples of faculty institutional assessment assignments. Observational data from the implementation of these workshops is also incorporated. A qualitative analysis that explores patterns and trends from the dataset for this study will be provided. Preliminary findings show the ways in which faculty adopted lessons learned from the workshop experiences and applied them to improve student learning in STEM environments. For example, in the CAT workshops, themes include: Developed activities and assessments on problem-solving, Developed activities and assessments on evaluating information, Collaboration among faculty assignments (sharing ideas, assignments, etc.), and Students made significant gains in critical thinking skills. At the AAC&U version of the workshops, major themes included: Move away from quizzes/tests/MC questions, integration of active learning activities (case studies, classroom activities, projects, research; intentional focus on criteria from AAC&U Rubric (5 different ways of evaluating student learning), and collaboration among faculty assignments (sharing ideas, assignments, etc.).

Conclusion This presentation will offer an overview of the creative, active learning opportunities that were developed from these workshops by faculty representing different disciplines. Implications from this study includes ideas and resources from the Center for Assessment and Improvement of Learning (CAIL) as well as guided critical thinking activities that faculty can implement to improve student learning and assessment. Implications and outcomes from this analysis include the relevance of incorporating active learning in workshops and the establishment of teaching and learning communities post workshop to engage in transformative thinking regarding student learning and evaluation.

References

American Association of Colleges and Universities [AAC&U]. (2023). Critical Thinking VALUE Rubric. *American Association of Colleges and Universities Valid Assessment of Learning in Undergraduate Education (VALUE)*. Retrieved from https://www.aacu.org/initiatives/value- initiative/value-rubrics/value-rubrics-critical-thinking

Avery, Z. K., & Reeve, E. M. (2013). Developing effective STEM professional development programs. *Journal of Technology Education*, *25*(1), 55–69. https://files.eric.ed.gov/fulltext/EJ1020199.pdf

DeMonte, J. (2013). High-Quality Professional Development for Teachers: Supporting Teacher Training to Improve Student Learning. *Center for American Progress*. https://files.eric.ed.gov/fulltext/ED561095.pdf

Haynes, A. and Stein, B. (2020). Observations From a Long-term Effort to Assess and Improve Critical Thinking, In F. Fair and D. Fasko (Eds), Critical Thinking and Reasoning: Development, Instruction, and Assessment (pp.231-254). Boston, MA: Brill Publishers.

Light, G., Calkins, S., Luna, M., & Drane, D. (2009). Assessing the Impact of a Year-Long Faculty Development Program on Faculty Approaches to Teaching. *International Journal of Teaching and Learning in Higher Education*, *20*(2), 168–181. https://files.eric.ed.gov/fulltext/EJ864334.pdf

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Affordances of Self-Study Methodology for Understanding Researcher Positionality

Samantha Fletcher (Middle Tennessee State University)

Abstract Self-study researchers have often posed the question of how mathematics teacher educators can expect pre-service teachers to reflect on their experiences and beliefs without engaging in reflective practices ourselves (Alderton, 2008; Pereira, 2005). Much self-study research has focused on improving teacher education, but self-study also allows researchers to gain insight into their research topic by considering personal experiences prior to examining data from others. Thus, the research question for this study was, **"How would I describe my mathematics identity during my experiences as a doctoral student preparing to be a mathematics teacher educator?"** In this self-study, I aimed to understand my own mathematics identity before conducting a dissertation about K-12 students' mathematics identities. During this presentation, I will share my findings from this self-study, which have the important implication for other STEM education researchers that self-study methodology can inform one's research trajectory by providing valuable connections to the researcher's positionality.

Background Literature

Self-Study Self-study can employ various methodologies and, thus, can be hard to define (Lynch et al., 2018), but a key feature is it "provides a process of reflection that allows one to deeply investigate aspects of personal practice" (Allen et al. 2016, p. 322). Similar to its use in this study, self-study has been used to compare experiences across contexts (Allen et al, 2016; Monroe, 2013; Skerrett, 2008). Self-study findings are often framed as tensions the subject experiences, for instance, between freedom and discipline (Alderton, 2008; Allen et al., 2016; Baker & Bitto, 2022; Bullock & Ritter, 2011; Monroe, 2013; Pereira, 2005). Self-study may be especially important for doctoral students (Allen et al., 2016; Lynch et al., 2018) and early career faculty (Bullock & Ritter, 2011) as they transition into academia. Specifically, doctoral students find themselves in multiple roles, which may make understanding oneself challenging (Allen et al., 2016). Finally, self-study can help with understanding one's identity (Allen et al., 2016; Bullock & Ritter, 2011).

Mathematics Identity In this study, I view identity as narrative. From this perspective, identity is "those narratives about individuals that are reifying, endorsable, and significant" (Sfard & Prusak, 2005, p. 11). Narratives are reifying when they describe the nature of a person rather than their actions and significant when they describe essential features about a person. Narratives are endorsable when the individual would view the narrative as an accurate representation of the world and a justification for their actions (Sfard & Prusak, 2005). Identity narratives are collections of stories through which the narrator makes meaning as they are written or told. In this study, my identity narrative was a reflective journal I wrote throughout the semester.

Purpose The purpose of this study was to understand my researcher positionality related to students' mathematics identities by understanding my own mathematics identity during my experiences preparing to be a mathematics teacher educator and researcher.

Methodology This study is part of a larger self-study of my mathematics identity in three different contexts during the Fall 2023 semester: taking an Abstract Algebra course, teaching an informal geometry course for pre-service elementary teachers, and completing a teaching internship in a fourth-grade classroom. Throughout these experiences, I wrote a reflective journal (Allen et al., 2016; Lynch et al., 2018), conducted observations of a teacher, conducted video-recorded 2 observations of myself, and engaged in audio-recorded discussions with critical friends using a self-study protocol adapted from Baker and Bitto (2021). The results for this study are preliminary based on the reflective journal.

Analysis To analyze the reflective journal, I drew from one phase of the Listening Guide method, understanding the first-person voice in the data (i.e., Listening for the "I"; Gilligan, 2015; Hall et al., 2018). The Listening Guide has been used to enable researchers to go beyond their own understanding of data and view phenomena through the voice of research participants (Gilligan, 2015). I took every I statement (pronoun and verb with or without the object) in the reflective journal to create an I-poem by listing them one after the other in the order they appeared (Gilligan, 2015). By creating and reading this I-poem, I explored how I described myself in relation to mathematics in each of the three contexts, looking for patterns in the I statements.

Summary of Findings Based on the I-poem, I can describe my mathematics identity in terms of key tenets, tensions, and shifts I experienced during the semester. From a young age, I was separated from others as an advanced mathematics learner, and this led me to expect myself to perform well in mathematics. After learning mathematics from a teacher who was passionate about the subject, I transitioned from exceling in mathematics for a grade to being passionate about the subject. As I entered an undergraduate program to prepare to teach secondary mathematics, I found it difficult to deal with mathematical concepts I did not immediately understand. Also, there was a tension between getting good grades and conceptual learning in my motivation to learn mathematics.

Later, my professional identity as a teacher became intertwined with my mathematics learner identity. As a result, my confidence in my ability to learn and teach mathematics often depended on a clear purpose for the content, structure, accessible labeling and notation, and sensemaking across contexts. The tension between grades and conceptual learning of mathematics manifested in my moment-to-moment teaching decisions in my informal geometry course related to assessment and meeting learning goals.

Through my experiences during the Fall 2023 semester, there were two major shifts in my mathematics identity. When I experienced feeling challenged in mathematics in Abstract Algebra, I became more comfortable with sitting with a lack of understanding until I could reason about it. By the end of the semester, through conversations with critical friends, I made the important shift from feeling like I did not know enough to be considered a mathematician to considering myself a mathematician based on my content expertise in K-12 mathematics education. My experience as a teaching intern in the fourth grade classroom contributed to this confidence.

Conclusion My goal for this study was to begin to address the research question, "How would I describe my mathematics identity during my experiences as a doctoral student preparing to be a mathematics teacher educator?" Through my analysis of my reflective journal entries during my experience as an instructor, student, and teaching intern, I was able to accomplish this purpose. Self-study methodology enabled me to describe key tenets, tensions, and shifts in my mathematics identity. Based on these preliminary results along with results of my larger study, I will establish a personal connection to my own mathematics identity useful for supporting my research into K-12 students' mathematics identity. Self-study methodology is a useful tool for any STEM education researcher to employ to inform their positionality in relation to their research topic.

References

Alderton, J. (2008). Exploring self-study to improve my practice as a mathematics teacher educator. *Studying Teacher Education, 4*(2), 95–104. https://doi.org/10.1080/17425960802433587

Allen, J., Rogers, M. P. & Borowski, R. (2016). "I am out of my comfort zone": Self-study of the struggle of adapting to the professional identity of a teacher educator. *Studying Teacher Education, 12*(3), 320–332. https://doi.org/10.1080/17425964.2016.1228048

Baker, C. K. & Bitto, L. E. (2021). Fostering a critical friendship between a program coordinator and an online adjunct to achieve reciprocal mentoring. *Studying Teacher Education, 17*(2), 188–207. https://doi.org/10.1080/17425964.2021.1903413

Baker, C. K. & Bitto, L. E. (2022). Interrogating the tensions of becoming antiracist mathematics teacher educators via critical friendship and rehearsals. *Studying Teacher Education, 18*(1), 80–97. https://doi.org/10.1080/17425964.2021.1997737

Ball, D., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Bullock, S. M. & Ritter, J. K. (2011). Exploring the transition into academia through collaborative self-study. *Studying Teacher Education, 7*(2), 171–181. https://doi.org/10.1080/17425964.2011.591173

Gilligan, C. (2015). The listening guide method of psychological inquiry. *Qualitative Psychology, 2*(1), 69–77. http://doi.org/10.1037/qup0000023

Hall, J., Towers, J, & Martin, L. C. (2018). Using I poems to illuminate the complexity of students' mathematical identities. *Educational Studies in Mathematics,* 99, 181–196. https://doi.org/10.1007/s10649-018-9839-y

Lynch, S., Andrew, K. Richards, R. & Pennington, C. (2018). "What's the middle ground? Am I ever going to be the perfect teacher?:" Self-study of a doctoral student's acculturation process, *Studying Teacher Education, 14*(2), 194–211.https://doi.org/10.1080/17425964.2018.1462154

Monroe, E. E. (2013). Being and becoming a mathematics teacher educator in and for differing contexts: Some lessons learned, *Studying Teacher Education, 9*(2), 96–107, https://doi.org/10.1080/17425964.2013.808044

Pereira, P. (2005) Becoming a teacher of mathematics. *Studying Teacher Education, 1*(1), 69–83,https://doi.org/10.1080/17425960500040015

Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher*, *34*(4), 14–22. https://www.jstor.org/stable/3699942

Skerrett, A. (2008) Biography, identity, and inquiry: The making of teacher, teacher educator, and researcher. *Studying Teacher Education, 4*(2), 143–156. https://doi.org/10.1080/17425960802433629

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Assessing Elementary Preservice Teachers' Knowledge for Fraction Division

Kingsley Adamoah & Jeremy Strayer (Middle Tennessee State University)

Introduction and Statement of Problem It is important for preservice teachers (PSTs) to develop a deep and connected conceptual understanding of the mathematical concepts they will teach (Ball, 1990; Da Ponte & Chapman, 2015). For this reason, a prominent goal of teacher preparation is to promote an understanding of the various ways students' reason about foundational mathematical ideas and practices (e.g., Ball, 1990; Ball et al., 2008; Even,1993; Hill, 2010; Li, 2008; Li & Kulm, 2008; Lo & Luo, 2012; Tirosh, 2000). Specifically, preservice elementary teachers have difficulty understanding fractions conceptually (e.g., Ball et al., 2001; Da Ponte & Chapman, 2015; Izsák, 2008). Relatedly, many prospective teachers graduate from teacher education programs with inadequate understandings of related concepts they will later teach such as fraction addition, subtraction, multiplication, and division (Ball, 1990; Ball et al., 2008; Lo & Luo, 2012). We argue that investigating PSTs' conceptions, connections, notions, and understandings of these specific mathematics concepts will provide support for designing effective interventions in content courses for teacher preparation. This study contributes to the existing body of research in identifying ways to strengthen aspects of teacher content knowledge that provides opportunities for strengthening students' mathematical learning and achievement (e.g., Hill et al., 2004; Rowland et al., 2005; Stylianides & Stylianides, 2010, 2014; Tchoshanov et al., 2017).

The goal of our study is to investigate preservice teachers' content knowledge (Ball et al., 2008) and content understanding (Bair & Rich, 2011; Hill et al., 2004; Hill et al., 2008) as the basis for measuring cognitive types of teacher content knowledge (Tchoshanov, 2011). Tchoshanov identified and defined three cognitive types of teacher content knowledge as the kind and quality of content knowledge and understanding teachers possess for the purpose of teaching. The cognitive types include knowledge of facts and procedures (**Type 1**), knowledge of concepts and connections (**Type 2**), and knowledge of models and generalizations (**Type 3**). We share results from the study for only Type 2 focusing on the concept of fraction division.

The research questions include:

1. What are PSTs' mathematical conceptions, connections, and notions of the fraction division concept?

2. How are PSTs' cognitive types of teacher content knowledge associated with their specialized content knowledge for the fraction division concept?

Guiding Frameworks Our analytic framework utilized a linear progression of constructs to answer the research questions. That is, content knowledge → cognitive types of teacher content knowledge → specialized content knowledge → content understanding → (mathematical conceptions, connections, and notions). Although our framework progresses linearly, we acknowledge that development of understanding does not. Our analysis of evidence of PSTs' conceptions, connections, notions, and knowledge supports this assertion.

Methodology and Timeline In this study, data was collected from 18 preservice elementary teachers enrolled in a mathematics content course focused on counting, number system, and operation topics, in the context of whole numbers and decimals at a public university in the southeastern United States. PSTs explored content as they engaged in conceptual reasoning, problem solving, and providing explanations and justifications for their solution strategies. We employed phenomenological analysis techniques to investigate PSTs' mathematical conceptions, connections, and notions of the fraction division concept.

The study included both quantitative and qualitative data collection processes. A modified form of the Teacher Content Knowledge Surveys (TCKS) designed by Tchoshanov (2011) was used to measure PSTs' content knowledge growth. Using multiple choice questions (a score of 0 for incorrect answer or 1 for a correct answer). Pre- and post-term exit tickets allowed PSTs to provide written feedback to mathematical tasks similar to each of the three cognitive types. The specialized content knowledge (SCK) progression framework (Bair & Rich, 2011) was also utilized to analyze these exit tickets. We delimited our analysis to the first component in the framework, which describes PSTs' ability to correctly solve a task, explain their work, justify their reasoning, and make connections. Bair and Rich's framework provided a fine-grained process for coding PSTs' SCK using a five-level progression of indicators which include entry (Level 0), emerging (Level 1), developing (Level 2), maturing (Level 3), and deep and connected mathematical knowledge for teaching (Level 4). The participants' written feedback to the exit tickets were then analyzed and assessed based on the five levels of the first component of the framework. The levels of the component provide evidence of progression in the quality of the content knowledge and the depth of understanding of the concept or task assessed. For example, Level 0 does not mean zero content knowledge of a preservice teacher but just a measure of progression in the quality of content knowledge of PST in the given task.

Data Analysis and Results Overall, PSTs' ability to identify key aspects of a problem was an essential indicator of well-developed reasoning based on SCK with a deep and connected understanding of mathematical concepts. For example, one participant who was at Level 4 stated that "*the question is asking how many ½ liters containers can be filled? So, it is a measurement division problem*". A problem solver's ability to identify specifics of a task is an indicator of understanding the problem before moving on to devising a plan and solving (Kilpatrick, 2016; Polya, 1945). A second indicator of explicit deep SCK reasoning was modeling tasks and justification in context. For example, PSTs at the developing stage (Level 2) had issues with justification to procedures by correctly connecting models to situational and solution equations. Those at the entry (Level 0) and emerging (Level 1) of SCK development had misconceptions of the meaning of the division equation $1\frac{3}{4} \div \frac{1}{2} = ?$ in the task. They were unable to demonstrate content understanding to see the difference between dividing in half and dividing by one-half. Our results also showed that Blair and Rich's (2011) SCK progression framework was associated with levels of knowledge as measured by the TCKS. We found that 30% of the PSTs with less than a numerical average value (< 0.5) of *Type 2* TCKS pre-post scores were those at Level 0 and Level 1 of SCK progression. Also, 40% of participants who were above average in TCKS scores were at Level 3 and Level 4 and the rest were at average.

Conclusion In conclusion, this study informs mathematics teacher educators on the characterization of the kind and quality of aspects of content knowledge and content understanding PSTs should possess for specific mathematical concepts. By asking all session attendees to consider sample PSTs work and use the SCK progression framework to analyze PSTs' exit tickets, we will explore the implications of our study's conclusions for ways that certain tasks might be incorporated in content courses for preparing preservice teachers.

References

Bair, S. L., & Rich, B. S. (2011). Characterizing the development of specialized mathematical content knowledge for teaching in algebraic reasoning and number theory. *Mathematical Thinking and Learning*, *13*(4), 292-321.

Ball, D. L. (1990). The mathematical understandings that prospective teachers bring to teacher education. *The elementary school journal*, *90*(4), 449-466. https://doi.org/10.1086/461626

Ball, D. L., Lubienski, S. T., & Mewborn, D. S. (2001). Research on teaching mathematics: The unsolved problem of teachers' mathematical knowledge. *Handbook of research on teaching*, *4*, 433-456.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Even, R. 1993. Subject-matter knowledge and pedagogical content knowledge: Prospective secondary teachers and the function concept. *Journal for Research in Mathematics Education, 24*(2), 94-116. http://dx.doi.org/10.2307/749215

Hill, H. C., Schilling, S. G., & Ball, D. L. (2004). Developing measures of teachers' mathematics knowledge for teaching. *Elementary School Journal*, *105*(1), 11–30. https://doi.org/10.1086/428763

Da Ponte, J. P., & Chapman, O. (2015). Prospective mathematics teachers' learning and knowledge for teaching. In *Handbook of international research in mathematics education* (pp. 287-308). Routledge.

Hill, H., Ball, D., & Schilling, S. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-Specific knowledge of students. *Journal for Research in Mathematics Education, 39*(4), 372-400. http://www.jstor.org/stable/40539304

Hill, H. C. (2010). The nature and predictors of elementary teachers' mathematical knowledge for teaching. *Journal for Research in Mathematics Education*, *41*(5), 513-545.

Izsák, A. (2008). Mathematical knowledge for teaching fraction multiplication. C*ognition and instruction*, *26*(1), 95-143.

Kilpatrick, J. (2016). Reformulating: Approaching mathematical problem solving as inquiry. In *Posing and solving mathematical problems* (pp. 69-81). Springer.

Li, Y. (2008). What do students need to learn about division of fractions? *Mathematics teaching in the middle school*, *13*(9), 546-552. https://doi.org/10.5951/MTMS.13.9.0546

Li, Y., & Kulm, G. (2008). Knowledge and confidence of pre-service mathematics teachers: The case of fraction division. *ZDM*, *40*, 833-843.

Lo, J. J., & Luo, F. (2012). Prospective elementary teachers' knowledge of fraction division. *Journal of Mathematics Teacher Education*, *15*, 481-500.

Polya, G. (1945). How to Solve It: A New Aspect of Mathematical Method. *Princeton University Press*: Princeton.

Rowland, T., Huckstep, P., & Thwaites, A. (2005). Elementary teachers' mathematics subject knowledge: The knowledge quartet and the case of Naomi. *Journal of mathematics teacher education*, *8*, 255-281.

Stylianides, G. J., & Stylianides, A. J. (2010). Mathematics for teaching: A form of applied mathematics. *Teaching and Teacher Education*, *26*(2), 161-172.

Stylianides, A., & Stylianides, G. (2014). Viewing "mathematics for teaching" as a form of applied mathematics: Implications for the mathematical preparation of teachers. *Notices of the AMS*, *61*(3), 266-276.

Tchoshanov, M. (2011). Relationship between teacher content knowledge, teaching practice, and student achievement in middle grades mathematics. *Educational Studies in Mathematics, 76*(2), 141–164.

Tchoshanov, M., Cruz, M. D., Huereca, K., Shakirova, K., Shakirova, L., & Ibragimova, E. N.(2017). Examination of lower secondary mathematics teachers' content knowledge and itsconnection to students' performance. *International Journal of Science and Mathematics Education*, *15*, 683-702.

Tirosh, D. (2000). Enhancing prospective teachers' knowledge of children's conceptions: The case of division of fractions. *Journal for research in Mathematics Education*, *31*(1), 5-25. https://doi.org/10.2307/749817

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The Interplay of Housing Instability and Mathematics during Adolescence: A Retrospective Study of Black STEM Folx

Sharetta Buford & Eliza Gallagher (Clemson University)

Introduction and Literature Review Few studies have delved into the delicate nuances that impact Black students' math performances, nor have they explored resources students leverage to overcome systems that perpetuate negative stereotypes about Black youth. One systemic hurdle that many Black children must navigate is housing instability. Housing instability is an alarming problem in the United States (U.S.) (Desmond, 2016). In fact, one in four adults in homes with children in the U.S. reported being behind on their mortgage or rent payments (Lloyd, Shaw, Alvira-Hammond, Hazelwood, & DeMand, 2021). This problem hits hard for Black families, with 50% of Black residents with children anticipating eviction or foreclosure within two months at the time of data collection (Lloyd et al., 2021). Housing instability, in any form, places students in challenging positions when trying to attend to their educational tasks. The impact is greater for families in poverty, so this research explores low-income students as poverty exacerbates experiences with housing instability.

Black poverty has been deemed worse than others in the U.S. (Desmond, 2016; Grusky, 2014; Sampson, 2012). Systemically, Black people are socially and economically disadvantaged, forcing them to stay in impoverished neighborhoods with less than adequate education funding (Grusky, 2014; Massey & Denton, 1993). Impoverished neighborhoods were intentionally constructed, built, and segregated to reinforce declining conditions in Black communities across the country (Grusky, 2014; Massey & Denton, 1993). Housing laws and racist practices were written and/or distributed in ways that intentionally kept people of color out of white neighborhoods and kept them in under-resourced neighborhoods (Desmond, 2016). Though many Black people have found themselves in systemically marginalized circumstances, their intellectual mathematics abilities should not be implicated by their living conditions.

Some Black youth have been socialized to believe they are not good at math. Stiff and Harvey (1988) asserted that Black students are more likely to be in remedial mathematics classes than their counterparts. Steele and Aronson (1995) found that Black students performed lower on standardized tests related to mathematics than White students when a stereotype threat was present. Stereotype threat is when a person complies with a negative view about a racial, ethnic, gender, or other group to which they belong (Steele & Aronson, 1995). Black adolescents, more so than any other race, perceive racial discrimination as early as middle school (Seaton & Douglass, 2014). Additionally, stress and anxiety can negatively affect the working memory when processing mathematical problems (Aldrup, Klusmann, & Ludtke, 2019). Stress can be exacerbated by inadequate living conditions; therefore, using Critical Race Theory (CRT) as a theoretical framework and Community Cultural Wealth (CCW) as an analytical lens, this work explores how Black adolescents excelled in mathematics despite experiences with housing instability and poverty (Delgado & Stefancic, 2017; Yosso, 2005).

Research Question and Significance Collectively, housing instability, poverty, Blackness, and mathematics create a powerful intersection that currently disadvantages Black youth; however, our research could bring awareness to this intersection and help redirect attention to students' environments rather than their learning abilities. This topic has scholarly significance as the findings will provide foundational knowledge of an underexplored topic that could be used to develop intervention studies to inform school policies in support of students experiencing housing instability. The exploration of housing instability and its potential effects on low-income, Black students' ability to focus on math in the U.S. is important because it has the possibility of debunking the dominant narrative that Black students innately perform lower in mathematics and math-related disciplines (Cvencek, Nasir, O'Connor, Wischnia, & Meltzoff, 2015). As such, our research question was, how did Black folx from low-income backgrounds overcome and/or cope with housing instability and excel in mathematics-related schoolwork during adolescence?

Methodology A multiple case study design was used to explore our question. Case study methodology is rooted in constructivism, a theory that considers one's experiences and perspective to be their truth (Baxter & Jack, 2008). Constructivism holds that truth is a construction of one's reality, and that reality becomes evident in storytelling (Baxter & Jack, 2008). Participants told us their lived experiences, thereby giving researchers chances to find patterns that informed new phenomena, theories, and practices. Each case was a Black person from a low-income background who majors(ed) in a science, technology, engineering, and/or mathematics (STEM) discipline. Multiple case study allows for the exploration of multiple cases within the same study and provides opportunities to hear from multiple students who may have never had the chance to tell others their stories. Multiple case study also affords opportunities to view participants' perspectives from different housing instability settings. A qualification survey queried experiences with housing instability and poverty during adolescence, prior experiences with mathematics, STEM interest, and an inventory of human and other resources that were meaningful to the respondent in their mathematical development. Semi-structured interviews were conducted to gather details regarding experiences with housing instability and ways in which participants leveraged different types of CCW, and follow-ups for participant validations will be scheduled as necessary. Zoom interviews lasted approximately 60-90 minutes and were recorded to the cloud for transcript access.

Data Analysis and Anticipated Findings To support the quality of this research, we are conducting a cross-case analysis (Yin, 1981; Yin, 2003), as well as an Epistemic Network Analysis (ENA) (Shaffer, 2017). Each of these analyses leave room for the researchers to look for patterns within the data rather than asserting one's assumptions. By highlighting the success of such students, we will provide counternarratives to push back against dominant narratives of Black youth as mathematical underperformers, raise awareness of the lack of governmental resources in impoverished communities, and accentuate the wealth of knowledge, support, and persistence situated in low-socioeconomic, Black communities. As Yosso (2005) introduced, there is rich CCW among traditionally marginalized and oppressed groups, and this work will share how students dealing with housing instability leveraged resources among the familial and neighborhood connections in their communities.

Conclusion This work will highlight the experiences of Black adolescents who experienced housing instability in a manner that will hopefully encourage policy makers and community leaders to provide more resources in impoverished neighborhoods. Moreover, we intend to accentuate the cultural wealth of knowledge and support from those within low-income communities who encourage and aid Black youth trying to navigate school while experiencing housing instability. By doing this, we hope educators will gain a deeper understanding of the circumstances some of their students have to endure. We want to provide historical context to help educators, policy makers, and education researchers understand how poverty found Black people, how housing instability affects students, how students have used CCW to leverage housing instability, and how educational policies and practices can be more equitable for students who experience housing instability.

References

Aldrup, K., Klusmann, U., & Lüdtke, O. (2020). Reciprocal associations between students' mathematics anxiety and achievement: Can teacher sensitivity make a difference? Journal of Educational Psychology, 112(4), 735–750. ttps://doi-org.libproxy.clemson.edu/10.1037/edu0000398

Baxter, P., & Jack, S. (2008). Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. *The Qualitative Report*, 13(4), 544-559.

Cvencek, D., Nasir, N. S., O'Connor, K., Wischnia, S., & Meltzoff, A. N. (2015). The development of math- race stereotypes: "They say Chinese people are the best at math." Journal of Research on Adolescence (Wiley-Blackwell), 25(4), 630–637. https://doi-org.libproxy.clemson.edu/10.1111/jora.12151

Delgado, R., & Stefancic, J. (2017). Critical race theory: An introduction (3rd ed.). New York University Press.

Desmond, M. (2016). Evicted: Poverty and Profit in the American City. New York: Broadway Books. Grusky, D. B., & Weisshaar, K. R. (Eds.). (2014). Social stratification: Class, race, and gender in sociological perspective. Boulder: Westview Press.
Lloyd, C. M., Shaw, S., Alvira-Hammond, M., Hazelwood, A. M., & DeMand, A. (2021). Racism and discrimination contribute to housing instability for Black families during the pandemic. ChildTrends. Retrieved November 29, 2021, from https://www.childtrends.org/publications/racism-and-discrimination-contribute-to-housing-instability-for-black-families-during-the-pandemic

Massey, D. S., & Denton, N. A. (1993). American apartheid: Segregation and the making of the underclass. In Grusky, D. B., & Weisshaar, K. R. (Eds.), Social stratification: Class, race, and gender in sociological perspective (pp. 31-38). Boulder: Westview Press.

Seaton, E. K., & Douglass, S. (2014). School diversity and racial discrimination among African-American adolescents. Cultural Diversity and Ethnic Minority Psychology, 20(2), 156–165. https://doi- org.libproxy.clemson.edu/10.1037/a0035322

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. Journal of Personality and Social Psychology, 69(5), 797-811.

Stiff, L. V., & Harvey, W. B. (1988). On the education of Black children in mathematics. Journal of Black Studies, 19(2), 190–203. https://doi.org/10.1177/002193478801900206

Shaffer, D.W. (2017). *Quantitative ethnography.* Cathcart Press.

Yin, R. K. (1981). The case study as a serious research strategy. *Knowledge: Creation, Diffusion, Utilization, 3*(1), 97-114.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, CA: Sage. Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. Race, Ethnicity and Education, 8(1), 69–91.

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Developing a Holistic Prototype to Wicked Challenges: A Theoretical Exploration of Graduate Student's Self-Efficacy within a Foundry-Guided Experience

Carey Wilson, Katie Pabody, Andrea Arce-Trigatti, Pedro Arce, Sabrina Buer, Ada Haynes, Rufaro Chitiyo, Robby Sanders, & Troy Smith (Tennessee Technological University)

Introduction Scholars studying traditional science, technology, engineering, and mathematics (STEM) disciplines have often noted identity and imposter syndrome elements in students, particularly those from underrepresented populations (McCullough, 2020). Scholarship indicates that student-centered and collaborative learning environments may provide strategies to help build student confidence and self-efficacy (Bean, 2011; Lang, 2016). Adopting a theoretical lens, this study explores graduate students' experiences in National Science Foundation - National Research Traineeship (NRT) program that offers an intentionally well-rounded interdisciplinary curriculum at a public, four-year, postsecondary institution. Guided by the Renaissance Foundry Model (i.e., Foundry), an innovation-driven learning platform, this program emphasizes the spirit of *Gadugi*, which features community-centered collaborations and partnerships. Exploring students' experiences concerning identity and imposter syndrome elements in this program may offer insight into how Foundry-guided programs support students' development.

Background in Literature & Significance of Study Student-centered and active learning strategies, applied to STEM disciplines, have often been lauded for learning through active and engaged student interaction (Felder & Brent, 2015; Lang, 2016). However, the scholarship also underscores that activity-based learning in undergraduate education is often applied as short bursts of group work activity with confined interaction set parameters (Bean, 2011; Lang, 2016). In contrast, innovation-driven learning strategies, like the Foundry (Arce et al., 2015), require extensive periods of student interaction within a student-centered environment engaged in interdisciplinary knowledge exchanges assisted by an integrated collaboration within students' teams within diverse disciplines. Although built on the foundations of active and student-centered learning, innovation-driven learning as fostered by the Foundry advances opportunities to build robust and collaborative learning techniques (Jorgensen et al., 2019), interdisciplinary communication skills (ArceTrigatti et al., 2019) and associated critical thinking and both problem identification and problem-solving skills (Sanders & Geist, 2016; Sanders et al., 2020).

Further, the need for efficient, interdisciplinary collaboration is a present challenge within STEM disciplines. Real-world problems are multifaceted and cannot be solved by a onesize-fits-all approach (Thibaut et al., 2018). To tackle today's wicked problems with an efficient approach, STEM students must also have the skills to work with and communicate with those outside their traditional disciplines respectfully and integratively Ludwig et al. (2017). investigated engineering, pre-nursing, and pre-health student interdisciplinary teams challenged to solve complex questions. In their study, the students improved their problem-solving skills and applied what they learned to future and past work while also seeing this as valuable for their futures in STEM. When applied to a student's studies, interdisciplinary courses can lead students to learn best practices in multidisciplinary teams by collaborating and working with others who may have diverse backgrounds and can bring potentially different views of the same challenge. However, this type of collaboration also necessitates strong communication skills, which may be influenced by self-confidence and self-efficacy.

Research Question The research question guiding this study is: What did graduate students gain regarding self-efficacy and disciplinary identity within a novel Foundry-guided interdisciplinary program?

Methodology Using a primarily qualitative methodology, this study will use theoretical frameworks guided by literature on self-efficacy in STEM to explore graduate student experiences in a Foundry-Guided program. Sandrone (2022) and McDonald et al. (2019) indicated that STEM self-efficacy is the individual's perception (or beliefs) of their ability, performance, and recognition of how these personal attributes align with their chosen STEM field of study or work. While participants in the program work with other graduate STEM students within the parameters of the Foundry model, they should develop vital teamwork skills, gain more problem identification and problem-solving tools, and develop efficient communication strategies. These positive experiences and potentially personal triumphs mimic Bandura's concept of self-efficacy: "What generalises [*sic*] is the belief that one can mobilise [*sic*] whatever effort it takes to succeed in different undertakings" (Bandura, 1997, p. 53). While building STEM efficacy, graduate students might also build their STEM identities and increase their sense of belonging within their chosen STEM fields.

Data Sources and Analysis The authors of this study collected data from reflections the graduate STEM students turned in after each cultural training experience, their required assignments, and other notes/memos. While the authors expect to find some themes closely related to self-efficacy within these data sources, they might also find cultural and other themes closely related to the Foundry model. Therefore, the authors will analyze the data using a combination of deductive and inductive approaches. With this process, the authors can better understand the graduate students' experiences in the program and share what might be added to existing literature.

Conclusion & Potential Findings Within STEM, students will need to work with a variety of people and different groups that represent various cultural representations. Working in interdisciplinary teams is critical to addressing wicked, real-world problems. Understanding how students can develop self-efficacy techniques that enhance their disciplinary identity and strengthen their role within their team is vital to this type of collaboration. Thus, this study offers a unique exploration of graduate students' experiences in a Foundry-guided program that intentionally integrates interdisciplinary skills in developing a prototype of innovative technology (Arce et al., 2015). Furthermore, due to the collaborative nature of the Foundry model, elements of this study might also offer insight into effective student engagement strategies in cultural competency that could be important for integrating into graduate STEM student experiences.

References

Arce, P. E., Sanders, R., Arce-Trigatti, A., Loggins, L., Biernacki, J. J., Geist, M., Pascal, J. A., & Wiant, K. (2015). The Renaissance Foundry: A powerful learning and thinking system to develop 21st century Da Vinci engineers. *Critical Conversations*: *An Interdisciplinary Journal*, *1*(2), 176–202.

Arce-Trigatti, A., Geist, M., & Sanders, J. R. (2019). Analysis of student communication strategies in an undergraduate, cross-disciplinary, collaborative course. *The Journal for Research and Practice in College Teaching, 4*(1), 1-22.

Bandura, A. (1997). *Self-efficacy*: *The exercise of control*. Freeman
Bean, J. (2011). Engaging ideas: the professor's guide to integrating writing, critical thinking, and active learning in the classroom (2 nd ed.). San Francisco: Jossey-Bass.

Felder, R. & Brent, R. (2015). *Teaching and learning STEM: A practical guide*. New York: John Wiley and Sons.

Jorgensen, S., Arce-Trigatti, A., Sanders, J. R., & Arce, P. E. (2019). "Promoting innovative learning strategies: A collaborative curricular re-design at the undergraduate level," Proceedings from the American Society for Engineering Education Southeastern Conference. March 10-12, 2019. Raleigh, North Carolina.

Lang, J. M. (2016). *Small teaching. Everyday lessons from the science of learning*. San Francisco: Jossey-Bass.

Ludwig, P. M., Nagel, J. K., & Lewis, E. J. (2017). Student learning outcomes from a pilot medical innovations course with nursing, engineering, and biology undergraduate students. *International Journal of STEM Education*, *4*(1), 1–14. https://doi.org/10.1186/s40594-017-0095-y

McCullough, L. (2020). Barriers and assistance for female leaders in academic STEM in the US. *Education Sciences*, *10*(10), 1–13. https://doi.org/10.3390/educsci10100264

McDonald, M. M., Zeigler-Hill, V., Vrabel, J. K., & Escobar, M. (2019). A single-item measure for assessing STEM identity. *Frontiers in Education*, *4*, 1–15. https://doi.org/10.3389/feduc.2019.00078

Sanders R, Geist M. Development and implementation of an interdisciplinary course at the interface of chemical engineering and nursing. *Proceedings of the American Society of Engineering Education*. 2016.

Sanders, J. R., Arce-Trigatti, A., & Arce, P. (2020). Promoting student problem identification skills via a Jeopardy-inspired course within the Renaissance Foundry. *Education for Chemical Engineers*, *30*(1), 49-59.

Sandrone, S. (2022). Science identity and its “Identity Crisis”: On science identity and strategies to foster self-efficacy and sense of belonging in STEM. *Frontiers in Education*, *7*, 1–9. https://doi.org/10.3389/feduc.2022.871869

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Van de Velde, D., Van Petegem, P., & Depaepe, F. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education.*European Journal of STEM Education*, *3*(1), 1–12. https://doi.org/10.20897/ejsteme/85525

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Meta-Analysis of Teaching Professional Development for STEM Graduate Teaching Assistants

Grant Gardner, Alyssa Freeman, Chelsea Rolle, & Kadence Riggs (Middle Tennessee State University)

Introduction Recent scholarship highlights the importance of *professional learning* for graduate teaching assistants (GTAs), including rigorous pedagogical preparation and research training (Authors, 2020; Denecke, 2017; Lane et al., 2018; Zotos et al., 2020). GTAs play an important role in the quality of undergraduate instruction; thus, holistic professional learning is essential for GTAs (Denecke et al., 2017; Wheeler et al., 2017). Additionally, GTAs can teach a large quantity of undergraduates throughout their programs and future careers (Connolly et al., 2016; Golde & Dore, 2001). As such, developing evidence-based teaching professional development (TPD) is critical for effective graduate training. Due to calls for changes in the professional learning of GTAs, there has been an increase in the number of publications related to GTA TPD. However, to our knowledge, there has not been a recent critical synthesis or meta-analysis that rigorously examines the impact of TPD on the relevant teaching outcomes of STEM GTAs. Therefore, this research aimed to conduct a meta-analysis of the GTA TPD literature to provide insight into the effectiveness of TPD on relevant outcomes. Specifically, we were interested in outcome variables for GTA cognition, GTA practices, and GTA impacts on undergraduate student learning outcomes (Authors et al., 2016). We asked the following research question: *What is the impact of TPD on STEM GTAs' cognitive outcomes, practice outcomes, and undergraduate student learning outcomes?*

Methods To answer our research question, we used the search terms (Table 1) to identify relevant publications in SCOPUS. This initial search resulted in a sample of n = 2,389 publications. Duplicates, books, and book chapters were removed from the sample, resulting in n = 1,758 articles. We used the following inclusion criteria to narrow down our sample: 1) written in English, 2) written after 1987 (the last major topical literature review), 3) sample of GTAs, 4) sample in a STEM field, 5) formal or informal PD intervention clearly described, and 6) specific intervention-driven outcomes were measured or evaluated. This left our remaining sample at n = 333 articles. We then read the remaining articles to determine if they had pre-post or quasi-experimental research designs. This resulted in a final sample of n = 29 with usable data for this meta-analysis.

Table 1: Search terms

Sample	Content
Graduate Student, Graduate Teaching Assistant, Teaching Assistant	STEM, Science, Biology, Chemistry, Physics, Mathematics, Engineering, Computer Science, Geosciences, Social Sciences, Sociology, Psychology, Astronomy, Physiology
Teaching	**Professional Development**
Teaching, Pedagogy, Pedagogical Content Knowledge (PCK), Curriculum, Instruction	Teacher Training, Professional Development, Socialization, Informal Professional Development, Workshops, Courses

Findings Of the 29 articles, n = 15 related to GTA cognition outcomes, n = 12 related to GTA practice outcomes, and n = 2 related to undergraduate outcome variables. There was insufficient statistical power to consider the undergraduate outcome variables in this meta-analysis. For conceptual validity, we further broke down the analysis of cognition outcomes into self-efficacy outcomes (n = 8) and teaching knowledge/belief outcomes (n = 7). We further broke down practice outcomes into observed teaching practices (n = 6) and undergraduate perceptions of GTA practices (n = 6). A complete meta-analysis utilizing a random effects model was run on the samples, resulting in four sets of findings aligned with: teaching self-efficacy outcomes, Table 1: Search terms teaching knowledge/beliefs outcomes, teaching practice outcomes, and undergraduate perceptions of teaching outcomes. To better understand the appropriateness of the data for this analysis, two homogeneity tests were conducted: Cochran's Q-Test and a I2 Test. All analyses except the sample with undergraduate perceptions of practice indicated appropriate sample homogeneity for a meta-analysis as indicated by large p-values. As Q is often undervalued with small sample sizes, we also conducted an I2 homogeneity test to estimate the percentage of variability across studies due to real differences and not chance. Results from this analysis were in line with the Q-Test, indicating low to moderate heterogeneity in three samples (low is typically < 25%, moderate generally is less than 50%). In interpreting the pooled g from the random effects model, only the self-efficacy meta-analysis shows a statistically significant positive effect. The impact of TPD development on GTAs' self-efficacy is positive, with an effect size of around 0.863 standard deviation units. For the impact of TPD on GTAs' beliefs/knowledge, we see a slightly positive effect size approaching significance but includes 0 within the confidence interval. Finally, the impact of TPD on GTAs' teaching practices is slightly negative (although not statistically significant).

Discussion/Conclusions From our meta-analysis, we found that there is almost no research linking STEM graduate student instructional quality to undergraduate student outcomes. This is concerning because many of the claims made about the efficacy of TPD to promote quality instruction should trickle down to student outcomes. However, there seems to be little empirical evidence of this connection. Secondly, our findings suggest evidence of significant effects of TPD on STEM graduate student self-efficacy but no other outcome variables. Finally, although not statistically significant, the effects of TPD on undergraduate student perceptions of STEM graduate student instructional quality are largely negative. This might reinforce previous studies that have shown novices are often met with student resistance when implementing new or innovative teaching strategies. Evidence-based and effective TPD have been studied extensively in the K-12 science education literature but less in a postsecondary context. There is very little quantitative research into best practices for GTA TPD from our sample, which should be addressed with future research.

References

Authors et al. (2016). *CBE-Life Sciences Education*.

Authors. (2020). *CBE-Life Sciences Education*.

Connolly, M. R., Savoy, J. N., Lee, Y.-G. & Hill, L. B. (2016). *Building a better future STEM faculty: How teaching development programs can improve undergraduate education*. Wisconsin Center for Education Research.

https://links.imagerelay.com/cdn/2210/ql/bb8ba5ac40984f4fa1121cbe01223940/Building_a_Better_Future_STEM_Faculty.pdf

Denecke, D., Feaster, K., & Stone, K. (2017). *Professional development: Shaping effective programs for STEM graduate students*. Council of Graduate Schools. legacy.cgset.org/publication-pdf/4062/CGS_ProfDev_STEMGrads16_web.pdf

Golde, C. M., & Dore, T. M. (2001). *At cross purposes: What the experiences of today's doctoral students reveal about doctoral education*. Pew Charitable Trusts. https://files.eric.ed.gov/fulltext/ED450628.pdf

Lane, A. K., Hardison, C., Simon, A., & Andrews, T. C. (2018). A model of the factors influencing teaching identity among life sciences doctoral students. Journal of Research in Science Teaching, 56, 141-162. https//doi.org/10.1002/tea.21473.

Wheeler, L. B., Maeng, J. L., Chiu, J. L., & Bell, R L. (2017). Do teaching assistants' matter? Investigating relationships between teaching assistants and student outcomes in undergraduate science laboratory classes. *Journal of Research in Science Teaching, 54*(5), 463-492. https://doi.org/10.1002/tea.21373

Zotos, E. K., Moon, A. C., & Schulz, G. V. (2019). Investigation of chemistry graduate teaching assistants' teacher knowledge and teaching identity. *Journal of Research in Science Teaching, 57*, 943-967. https://doi.org/10.1002/tea.21618

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The Relationship between Autonomy, Pedagogical Discontentment, Self-Efficacy and the Teaching Practices of Graduate Teaching Assistants

Alyssa Freeman, Grant Gardner, Chelsea Rolle, Kadence Riggs, & Tom Brinthaupt (Middle Tennessee State University)

Introduction Holistic teaching professional development (TPD) is essential given the critical role graduate students play in the *quality* of undergraduate instruction (Denecke et al., 2017; Wheeler et al., 2017) and the *quantity* of undergraduate students they may teach throughout their programs (Connolly et al., 2016). However, the voluntary engagement of graduate students in TPD is limited (Schussler et al., 2015). Pedagogical discontentment, a state of cognitive conflict between an individual's teaching goals and classroom practices, has been shown to drive voluntary engagement of instructors in TPD (Kahveci et al., 2018; Southerland et al., 2011). Research has proposed a relationship between an instructor's pedagogical discontentment and their teaching self-efficacy (Southerland et al., 2011). When pedagogical discontentment is experienced in instructors with high self-efficacy, they may attempt new practices. Instructors with low self-efficacy who experience pedagogical discontentment may engage in avoidance behaviors (Gess-Newsome, 2015; Southerland et al., 2011).

The development of pedagogical discontentment might not occur in classrooms where instructors do not define their teaching goals and practices. Perceived limited teaching autonomy may be an important factor for the professional development of GTAs as they do not typically design their course curriculums (Dillard et al., 2023; Flaherty et al., 2017; Winters & Matusovich, 2011). TPD programs and autonomy can influence GTAs' perceptions of pedagogical discontentment, self-efficacy, and their practices. This study evaluated a GTA TPD program by analyzing relevant outcome variables for GTA cognition (pedagogical discontentment, self-efficacy, and autonomy) and GTA teaching practice outcomes (use of student-centered teaching practices). Our research question was: Does perceived autonomy relate to GTAs' pedagogical discontentment, self-efficacy, and instructional practices?

Methods

Description of PD The graduate school of a large public institution in the Southeastern United States offered a voluntary semester-long TPD opportunity to university GTAs. The program met weekly and addressed non-discipline-specific issues related to teaching and learning. GTAs participated in teaching workshops, writing reflections, microteaching activities, teaching observations, and developed a teaching philosophy statement.

Data Collection We used a quasi-experimental pre-post survey design to collect data on 141 participants over six years. Each survey item was from previously published literature and, therefore, has some established validity and reliability evidence. The pedagogical discontentment scale has four subscales related to dissatisfaction with: teaching all students regardless of ability, content knowledge of science, balancing depth and breadth of instruction, and assessing student learning (Southerland et al., 2012). The GTA self-efficacy survey contains two subscales for GTA confidence: promoting a productive learning environment and using various instructional strategies (DeChenne et al., 2012). We used the postsecondary instructional practices survey to describe the GTAs' teaching practices as instructor or student-centered (Walter et al., 2016). The GTAs also indicated the level of decision-making they have from autonomous ("I make all the decisions on what and how to teach the course"), some autonomy ("I can make decisions on how to teach but not what to teach in the course"), no autonomy ("Someone else makes the decisions 2 on what and how to teach the course"), or group autonomy ("I am part of a group that makes the decisions on what and how to teach the course").

Data Analysis To answer our research question, we used arbitrary cutoffs from the Likert scale to categorize the GTAs as having pedagogical discontentment, pedagogical contentment, high self-efficacy, or low self-efficacy. These cutoff values were determined based on the individual survey instrument scales. The pedagogical discontentment Likert scale cutoff was decided at a two, the "moderately discontent" response. Since the pedagogical discontentment survey has four subconstructs, we used the sum of the subconstructs to produce a cutoff value of eight. The cutoff for the self-efficacy Likert scale was determined at a three, the "somewhat confident" response, which resulted in a cutoff value of six.

Findings

Pre-Survey Most GTAs were content with their teaching (90%; Figure 1A). Of these GTAs, 53.75% reported having high self-efficacy, and 36.25% reported low self-efficacy. Of the content GTAs, 24% report using student-centered practices. 10% of the GTAs reported discontentment during the pre-survey with high (2.5%) or low (7.5%) self-efficacy. None of the discontent GTAs indicated their use of student-centered teaching practices. Most GTAs reported having some autonomy (37.5%) with variable self-efficacy. Many GTAs reported having no autonomy (35%).

Post-Survey The majority of the GTAs were content with their teaching (94.22%; Figure 1B) with either high (78.84%) or low (15.38%) self-efficacy. Of the content GTAs, approximately 42% report using student-centered teaching practices. Only 5.76% of the GTAs were discontent with their teaching, and all reported low self-efficacy. Additionally, the discontent GTAs did not report using student-centered teaching practices. GTAs during the postsurvey indicated that they had some autonomy in their teaching (46.15%), but 25% of GTAs indicated having no autonomy. Many GTAs who reported having some or no autonomy in their teaching reported pedagogical contentment and high self-efficacy.

Discussion and Conclusions While it is incredibly promising that the frequency of student-centered teaching practices nearly doubled (24% to 42%), many GTAs did not report using student-centered teaching practices after the TPD. Additionally, our findings indicate that many GTAs were not in a position to change their teaching practices after the TPD to be more aligned with student centered teaching practices (i.e., they did not report discontentment with high self-efficacy). In this study, we also argued that perceived teaching autonomy is important for GTAs to be in a place to change their teaching toward student-centered teaching practices. However, many of the GTAs in our sample did not report a sense of autonomy. Thus, it will be important for future research to consider how to productively foster GTA pedagogical discontentment while supporting their self-efficacy and autonomy to adopt student-centered teaching practices.

References

Authors et al. (2016). *CBE-Life Sciences Education*.

Connolly, M., Savoy, J., & Lee, Y.-G. (2016). *Building a better future STEM faculty: How teaching development programs can improve undergraduate education*. Wisconsin Center for Education Research.

DeChenne, S. E., Enochs, L. G., & Needham, M. (2012). Science, technology, engineering, and mathematics graduate teaching assistants teaching self-efficacy. *Journal of the Scholarship of Teaching and Learning*, *12*(4), 102–123.

Denecke, D., Feaster, K., & Stone, K. (2017). *Professional development: Shaping effective programs for STEM graduate students*. Council of Graduate Schools.

Dillard, J. B., Sadek, K., & Muenks, K. (2023). Undergraduate perceptions of graduate teaching assistants: Competence, relatedness, and autonomy in practice. *Higher Education Research and Development*, 1–17. https://doi.org/10.1080/07294360.2023.2215169

Flaherty, A., O'Dwyer, A., Mannix-McNamara, P., & Leahy, J. J. (2017). The influence of psychological empowerment on the enhancement of chemistry laboratory demonstrators' perceived teaching self-image and behaviours as graduate teaching assistants. *Chemistry Education Research and Practice*, *18*(4), 710–736. https://doi.org/10.1039/C7RP00051K

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In *Reexamining pedagogical content knowledge in science education* (pp. 28–42). Routledge.

Kahveci, A., Kahveci, M., Mansour, N., & Alarfaj, M. M. (2018). Exploring science teachers' affective states: Pedagogical discontentment, self-efficacy, intentions to reform, and their relationships. *Research in Science Education*, *48*(6), 1359–1386. https://doi.org/10.1007/s11165-016-9606-y

Leshner, A., & Scherer, L. (2018). *Graduate STEM education for the 21st century: Consensus study report*. National Academies Press.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). *Accommodation of a scientific conception toward a theory of conceptual change*. *66*(2), 211–227.

Schussler, E. E., Read, Q., Marbach-Ad, G., Miller, K., & Ferzli, M. (2015). Preparing biology graduate teaching assistants for their roles as instructors: An assessment of institutional approaches. *CBE Life Sciences Education*, *14*(3), 1–11. https://doi.org/10.1187/cbe-14- 11-0196

Southerland, S., Nadelson, L., Sowell, S., Saka, Y., Kahveci, M., & Granger, E. M. (2012). Measuring one aspect of teachers' affective states: Development of the science teachers' pedagogical discontentment scale. *School Science and Mathematics*, *8*, 483–494.

Southerland, S., Sowell, S., Blanchard, M., & Granger, E. M. (2011). Exploring the construct of pedagogical discontentment: A tool to understand science teachers' openness to reform. *Research in Science Education*, *41*, 299–317.

Walter, E. M., Henderson, C. R., Beach, A. L., & Williams, C. T. (2016). Introducing the postsecondary instructional practices survey (PIPS): A concise, interdisciplinary, and easy-to-score survey. *CBE—Life Sciences Education*, *15*(4), 1–11. https://doi.org/10.1187/cbe.15-09-0193

Wheeler, L. B., Maeng, J. L., Chiu, J. L., & Bell, R. L. (2017). Do teaching assistants matter? Investigating relationships between teaching assistants and student outcomes in undergraduate science laboratory classes. *Journal of Research in Science Teaching*, *54*(4), 463–492. https://doi.org/10.1002/tea.21373

Winters, K., & Matusovich, H. (2011). Graduate teaching assistants' decision making and perceptions of autonomy. *2011 ASEE Annual Conference & Exposition Proceedings*, 22.757.1-22.757.13. https://doi.org/10.18260/1-2--1803

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Beyond gender and race: The representation of concealable identities among college science instructors

Carly Busch, Katelyn Cooper, & Sara Brownell (Arizona State University)

Abstract Concealable stigmatized identities (CSIs) are identities that can be kept hidden and carry negative stereotypes depending on the culture of a particular context; common examples of CSIs in the U.S. are mental health conditions and LGBTQ+ identities. Students often look to their professors as role models based on identities that tend to be apparent (e.g., gender or race), but an individual must disclose a concealable identity for others to relate to them. In order to understand the potential influence instructors have as role models for their students based on CSIs, we must first explore the identities instructors have and whether they disclose those identities to their students. There is little known about to what extent professors have CSIs and what factors influence whether they share them with students. To address this gap in the literature, we conducted a study to examine (1) to what extent science instructors hold concealable stigmatized identities, (2) whether they reveal those identities to undergraduates, (3) how the prevalence of CSIs among instructors compares to undergraduates, and (4) what are the primary factors influencing instructors' decisions to reveal or conceal such identities. Our research questions encompassed a range of ten CSIs including being a first-generation college student, growing up in a low-income household, and having anxiety.

We used the disclosure process model (Chaudoir & Fisher, 2010), which outlines common reasons for concealing a CSI, to construct a survey to answer our research questions. We surveyed a national sample of instructors across the sciences (i.e., biology, chemistry, geosciences, physics) from very high research (R1) institutions; we sent the survey out to all faculty and instructors at all R1 institutions (over 40,000 individuals) and 1,248 participated in the study. We asked a suite of demographic questions, including potential CSIs. Participants then indicated if they revealed these identities formally to all students in their undergraduate courses, during informal settings (e.g., office hours) to some students, or if they never shared these identities with undergraduates. We also surveyed participants about the reasons they choose to reveal or conceal their identities. Next, we surveyed a national sample of science undergraduate students at R1 institutions (n=2,428) to assess the prevalence of the same set of ten CSIs. We calculated the discrepancies in prevalence of CSIs by subtracting the percent of undergraduates who reported the identity from the percent of instructors.

The most common CSIs instructors reported were having anxiety (35%) and being a first generation college student (29%). Relatively few instructors revealed CSIs to students. The largest mismatches of CSI prevalence were for struggling academically in college (-30%) and having anxiety (- 25%); all mismatches grew when accounting for instructor CSI disclosure. Across all CSIs, the most common reasons instructors revealed their identity to all undergraduates in their courses were a desire to be a known supporter of individuals with that identity, to be an example of someone with that identity, and they typically share the identity with others. Conversely, the most common reasons instructors chose to conceal their identities were that it was not relevant to course content, not relevant to students in the course, and the instructor typically does not share the identity with others.

Currently very little is known about the representation of science instructors beyond racial and gender identities. Given the potential for instructors to act as role models for students, understanding what identities instructors hold and the extent to which they share them with students is important to consider as we work toward creating a more diverse and inclusive scientific community. This work highlights an array of CSIs held by instructors, identifies the extent to which instructors may be serving as role models for students in science, and suggests changes that institutions can make to create more welcoming environments for instructors holding CSIs. Finally, this work serves as a foundation for future research on a variety of identities and the potential impact instructors can have on their students by revealing them.

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The Influence of Cultural Perceptions in the Preference and Choice of STEM Programs

Priscilla Moffat (Ghana Institute of Management and Public Administration)

Abstract This study explored perceptions rooted in and acquired from the cultures of many developing countries and how they impact applicants' preferences and choices of STEM programs. The context of developing countries was chosen for this study because gender role socialization continues to maintain an important place in most of these cultures.

This study's relevance rests in the fact that, as the world takes steps to encourage and promote the choice and study of STEM programs, especially among females, there is the need for efforts towards understanding various cultural perceptions towards some programs of study, particularly STEM programs, which have diverse gender attributions in many developing cultures. Also, as the world strives to achieve gender equity in education, such a study comes handy, as it provides useful understanding of the underlying cultural factors that affect study program preferences of applicants, particularly in developing countries like Ghana as well as others in Africa.

The study analyzed the admission application data of five public universities in Ghana. 1600 randomly-sampled final-year students of 32 randomly-selected senior high schools from the 16 regions of Ghana were interviewed. Since parents and teachers often guide and influence the study program choices of applicants, the study examined the perceptions of 180 teachers and 360 parents.

The study found, among other things, that STEM programs are commonly perceived to pose much more difficulty to females than they do to males. As a result, many female applicants are discouraged from choosing these programs. While nursing programs are perceived more as programs for females, with the justification that females are better caregivers, males are perceived to be better medical doctors, engineers and computer technicians. Thus, many females are less encouraged to choose Technology and Engineering programs.

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The Influence of Near-Peer Mentoring on Undergraduate Career Goal Development in a Community of Research Teams

Thomas Stiles (University of Montana Western)

Significance To dramatically increase the number of university STEM research opportunities, the barrier of limited faculty mentoring time must be addressed. To address time constraints, faculty researchers often rely on a more advanced student to help mentor a novice undergraduate. This "two-on-one" approach, however, does little to scale-up the available opportunities for the many undergraduates wanting to get involved and explore STEM research as a career (Linn et al., 2015). To address this problem, some programs have conducted research in faculty-mentored, student led teams (Feldman et al., 2013; Sturner et al., 2017); and still others have extended this approach by organizing large numbers of students and faculty into communities of research teams (Author; Kobulnicky & Dale, 2016). The present work therefore aims to examine how the time that community members spend mentoring others might influence undergraduates' decisions to pursue a STEM research career.

Background For this study, undergraduate researchers were recruited from a community of STEM research teams. Participation in this program is negotiated at the team level as less experienced students seek to join the research projects of faculty-mentored, student-led teams. Because the program provides no monetary incentives or time requirements, an undergraduate's role on the team is negotiated as participants decide how to pursue project goals. Voluntary student-led team leader meetings are also held to explore issues in project management and mentoring.

The undergraduate population in this program is not only sizeable, but more diverse than university apprenticeship programs. Selective recruitment in those programs results in participants who are mainly juniors and seniors with high grades (Lopatto, 2007; Russell et al., 2007). In contrast, this program has no selection criteria and helps all students join a team. Consequently, there are students from all academic classes with more diverse career development goals (Author).

The mentoring that occurs within a team-based community involves more interactions than apprenticeship programs. Instead of mentoring one student, advanced students in this program lead project teams composed of multiple undergraduates. In addition to working with a research team, an undergraduate works with a student team leader and a faculty mentor. The team leader also works with the faculty mentor as well as other team leaders. As others have suggested (Feldman et al., 2013; Kobulnicky & Dale, 2016), the multiple mentoring interactions in a team community can accelerate undergraduates' development of competencies and career goals.

Question/Hypotheses Given this more complex network of interactions, career goal change may not necessarily depend on the absolute time spent with a particular mentor. Instead, the amount of time spent with a mentor relative to the amount of time spent with the research team might be an influential factor. Given this question, the following hypotheses were formed:

H1. The relative level of mentoring that a team member or team leader receives from others in the research community will influence an undergraduate's decision to pursue a research career.

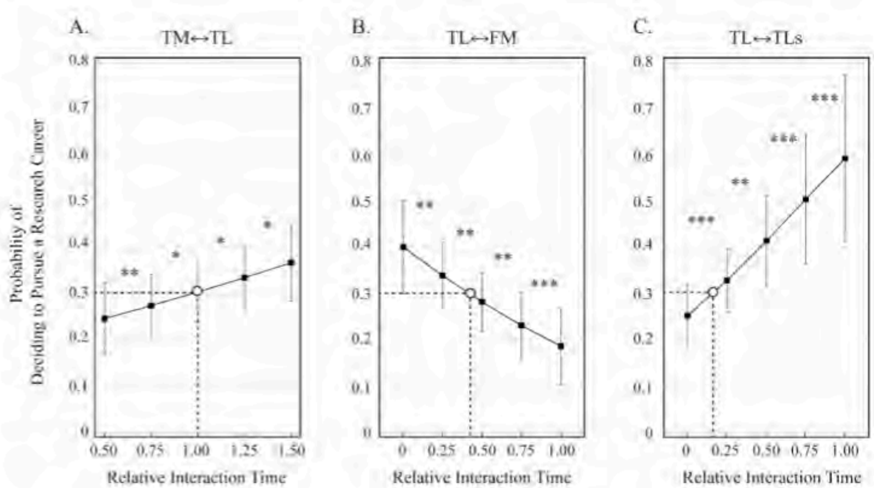
H2. Adjusting the relative levels of mentoring in a team-based research community can increase the probability that undergraduates will decide to pursue a research career.

Analysis Methods Survey data was collected from a diverse population of undergraduates participating in a large team-based research community. The binary outcome variable of deciding to pursue a research career was quantified by identifying a subsample of consenting undergraduates who joined the program with no prior plans to pursue a research career (n = 200). The ratio of time these undergraduates spent with a particular mentor to the time they spent with a research team was calculated. Binary logistic regression was then used to assess the influence of mentoring times and team research times on undergraduate career goal change. The academic class, gender, and grade point average of undergraduates as well as the academic level of team leaders were controlled.

Results To evaluate whether relative mentoring levels affected an undergraduate's decision to pursue research, a logistic model was made ($F_{8, 192} = 2.08$, $p = 0.039$). In this model, the ratio of mentoring time to team research time was found to be a robust measure of mentoring interactions that influence undergraduate career goal change in a research intensive community. Using this measure, the study found (1) mentoring of a team member by a student team leader and (2) mentoring of a team leader by other student team leaders have a positive influence. In contrast, (3) mentoring of a team leader by a faculty mentor has a negative influence on decisions to pursue a research career. Figure 1 shows the predictive margins for these relative levels of mentoring.

Figure 1.

Open circle (○) and dashed lines indicate the average probabilities at observed values. The significance of a margin difference is indicated between adjacent probability predictions ($^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$).



Conclusions These findings suggest that a community of teams can provide well-mentored STEM research experiences for large numbers of students without further investments of faculty time. In fact, the predictive margins illustrated in Figure 1 suggest that if team leader mentoring by faculty (TL←FM) were decreased from 0.42 to 0.25 and team leader mentoring by other team leaders (TL←TLs) were increased from 0.18 to 0.25, then the probability of career goal change would rise to .357 ($t = 8.85$, $p = 0.000$). For these small adjustments, this is an approximate 6% increase ($t = 2.91$, $p = 0.004$). Depending on program size, these adjustments would increase the number of undergraduates deciding to pursue a research career by a modest amount over the years. So by modeling the different types of mentoring that occur in a research community of teams, programs can be optimized to minimize faculty mentoring time and increase the probability that undergraduates will decide to pursue a STEM research career.

References

Author.
Feldman, A., Divoll, K. A., & Rogan-Klyve, A. (2013). Becoming researchers: The participation of undergraduate and graduate students in scientific research groups. Science Education, 97(2), 218-243.

Kobulnicky, H. A., & Dale, D. A. (2016). A community mentoring model for STEM undergraduate research experiences. Journal of College Science Teaching, 45(6), 17. Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. Science, 347, 627-633.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. CBE—Life Sciences Education, 6(4), 297-306.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. Science, 316(5824), 548-549.

Sturner, K. K., Bishop, P., & Lenhart, S. M. (2017). Developing collaboration skills in team undergraduate research experiences. Primus, 27(3), 370-388.

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A Research-Based Dual Enrollment Statistics Class at ETSU

Maria Emilia Alfaro, John Hicks, & Anant Godbole (East Tennessee State University)

Introduction The United States Department of Education recently awarded a $9 Million, five-year EIR grant to the Niswonger Foundation of Greeneville, Tennessee, USA ("The Foundation"). In writing its proposal for funding, The Foundation was guided by the concept of Learning Design (L.D.), defined as "the creative and deliberate act of devising new practices, plans of activity, resources and tools aimed at achieving particular educational results….". Indeed, the grant is unfolding using Learning Design as its underlying principle. Refer to https://niswongerfoundation.org/about/stem-ld/ and https://www.etsu.edu/coe/stem-education/niswonger_stem_ld.php for further information about the Foundation's STEM.LD Project.

The STEM.LD Grant, as outlined by The Foundation, focuses on three components: **a.** Strengthening the teaching and learning classroom experiences with engaging materials for students, combined with the professional development of their teachers,

b. Experimental out-of-school-time (OST) opportunities to explore the diversity of STEM content, and

c. Expanding participation in rigorous STEM and dual enrollment classes.

Our Project At ETSU, we are focused on a. and c. above. Through this proposal, we want to describe our efforts in building and evaluating a dual enrollment Statistics class (MATH 1530), which will enable students to fulfil the Tennessee Statistics course requirements while, simultaneously, introducing them to open-source software such as R. The class is offered to eligible juniors and seniors primarily from the following six STEM-LD Partnership school districts: Cocke County, Hawkins County, Johnson County, Unicoi County, and Washington County.

The Class MATH 1530, 3 credits, is being taught as an asynchronous section of Probability and Statistics for the first time as a dual enrollment course during Fall 2023 (Year 3 of the project) as a 15-week long course. The course currently has 19 students enrolled and we expect this number to grow in Years 4 and 5. Engaging students with real-life data sets, and enabling them to analyze them, will prepare students both for College and Career, and our Statistics course is therefore in the spirit of a STEM course, where we always use the acronym in its 2.0 version, i.e., engaged interdisciplinary and multidisciplinary content that crosses bridges between academic disciplines.

A text written by the first and second authors of this paper, is used as the primary source. This text [1] is titled *Statistics with Technology for High School,* and is indeed one of the key products of the ETSU-Foundation partnership. The course is based on the analysis of data sets, small and large, in the context of key introductory statistical methods such as descriptive and graphical statistics, confidence intervals, hypothesis tests, and regression. It is suitable for all STEM students, whether they are headed towards college or career. Even though there do exist books for Statistics instruction at the high school level, e.g., [2, 3] the present book features strict adherence to the Tennessee Mathematics Standards [4]; a complete incorporation of Open-Source software; and a focus on key concepts, as in all sections of the MATH 1530 course taken by close to 2000 students each year at ETSU. Even though Python has been tried to be implemented in High-schools across the globe, see e.g., the research articles [5], [6], our approach has been to use R in the context that it was originally intended to be used, and we believe that [1] can be of great benefit for diverse audiences of students, including students needing remediation, English language learners, and other groups.

Research Question Specifically, we are targeting to answer the following two questions:

Can Statistics be taught successfully using open-source software that is commonly used in

college, to create a learning experience that is practical, contemporary, and high-impact?

Can we move beyond TI-83's in high school?

Research Approach At its core, this project is an initiative to introducing the use of technology and open- source software in statistics at a stage earlier than college. However, with the aim of analyzing the efficiency of this initiative from the student's standpoint, as part of the project, the instructor of the course will be administering two questionnaires to the students (one in the beginning of the course and one in the end), aiming to gather information about expectations, results, understanding and overall experience. The collection and analysis of these responses will provide an opportunity for us to evaluate the efficiency of the current initiative.

Timeline We are currently at the data collection step for the analysis of the project performance. Additionally, we plan to re-run this survey each time the course is taught, and analyze the results as we progress in our initiative. We expect to present our first set of results after conducting the analysis in the end of the semester.

Conclusion In summary, our project is aligned with the goals set forth by The Foundation's grant and aims to represent a significant step toward advancing STEM education by equipping high school students with the skills and tools they need for success in an increasingly data-driven world. Through ongoing assessment and upcoming analysis, we are committed to ensuring the continued improvement and efficiency of our educational initiative.

References

[1] Alfaro, M. E. and Hicks, J. Statistics with Technology for High School. 2023.
[2] Illowsky B. and Dean S., Statistics for High School (hardcover). 1st ed. OpenStax; 2023.
[3] Starnes D. S. and Tabor J., Statistics and Probability with Applications (High School). 3rd ed. W.H. Freeman; 2020.
[4] Algebra II instructional focus documents. Www.tn.gov. Accessed August 19, 2023. https://www.tn.gov/content/dam/tn/education/standards/math/Standards_Support_Alg_II_Mathematics.pdf
[5] Sarkar S. and Sarkar S., A new approach to teach molecular biology in high school using Python. IEEE Region 10 Humanitarian Technology Conference (R10-HTC), Agra, India, 2016.
[6] Elkner, J. Using Python in a High School Computer Science Program. 1999.

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Strategic Planning Platform for Engaged Regional Research and Industry Development

K. Madeline Boykin (University of Alabama at Birmingham), Gabriela Gurau, Robin Rogers, Jonathan Bonner (Unaffiliated), Jeff Gray, Chris Crawford (The University of Alabama), Tasha Drake (Stillman College), & Brian Pillay (University of Alabama at Birmingham)

Introduction Community of Stakeholder members were identified from key sectors in rural Alabama for a Small Business Innovative Research Phase I project from the U.S. Department of Energy to create a strategic partnership for Education and Outreach (EO). Stakeholders were provided a project overview and asked to develop a framework for introducing new green industrial and workforce technology ideas based on a Chitin Ionic Liquid Extraction Process (CILEP). New portable industrial pilot units are being developed to sell for processing biomaterials, *creating new businesses and unique jobs that will require community support and engagement to adopt the technology and help with successful implementation. The project was conducted as a community led activity to generate a "Strategic Planning and Implementation Template"* for replication using subsequent technology introduction for industry, workforce education, and community support.

The EO project was led by a rural non-profit, the Hale Empowerment and Revitalization Organization (HERO), whose mission is to serve as a catalyst to end rural poverty. HERO began in 1989 with assistance from administration, researchers, and educators at the University of Alabama System with Provost Mac Portera efforts supporting rural Blackbelt strategic planning. To assist with broad dissemination to community based programs across the region for preparing critical workforce and skill building projects in rural and low income communities, HERO is as part of the Fahe Network, Berea, Kentucky, serving local, regional, and national community leaders in their support of growing basic infrastructure and human resources.

Community, Educational, and Research Goals The hypothesis for the project was *if and how a George Washington Carver Translational Science Model (Zavgorodnya, 2017) could be presented to students and community members to identify new products and business concepts for promoting and developing unique geographical biomaterials-based industries and workforce.* Translation of new sustainable technologies from academia to industry and their commercialization is less based on the technology itself and more on cost and demonstration of viability and significant improvements over the current practice. Education and Outreach explored the question: *Could the workforce concurrently benefit from the introduction of new technology while stimulating entrepreneurial training and programming?*

The goals of the planning grant were to: (1) Illustrate to a specific community how a biorefinery can be used to make a local waste into a local resource, specifically in this case the CILEP in Bayou La Batre, Alabama; (2) Provide transitional knowledge illustrating to underutilized communities the potential for high biomass industries, involve students and community stakeholders, to give them a vocabulary and resources to recognize, explore and capitalize on opportunities stemming from a national goal of net-zero carbon emissions by 2050; and (3) Develop the guidelines for a coherent Phase II education and outreach plan that can be useful to accompany any biorefinery project such as the CILEP in other communities.

The research team assembled stakeholders linking Coastal Alabama and Black Belt into a Community Stakeholder Partnership. The areas share common economic interests; both are heavily reliant on the fishing industry (Petterson et al., 2006). Coastal Alabama draws resources from the Gulf of Mexico while the Alabama Black Belt is home to the State's catfish industry. In the past ten years, both highly productive areas have been economically depressed (Abbot-Jamison, 2015; Upton, 2011, Jackson, 2007) and have large populations of underrepresented groups and impoverished individuals. The groups or individuals were selected from Education, Social/Economic Development, and Business (industry) important to partnerships seeking a broad range of views on community needs, workforce preparation, economic development and investment return: <u>Key concept #1 is "Societal understanding requires the input of the societal spectrum".</u> The team consisted of experts from: 525 Solutions, Gulf Coast Agricultural and Seafood Coop, Alma-Bryant High School, Bayou La Batre Chamber of Commerce, HERO, Hale 2 County Chamber of Commerce, Hale County College & Career Center, Kyser Catfish Farms, Hale County Cooperative Extension, University of Alabama, Stillman College, and Central Alabama Community College. Diverse programs are essential in pipeline innovation for the emerging biomass materials industry (Constante, 2015; Roy, 2012; Baker, P., 2002, Boykin, 2019).

Methodology Community Stakeholders were presented background on George Washington Carver as the father of the peanut industry who developed more than 300 uses for peanuts (e.g., shampoo, glue, etc.) and helped save agriculture in the South (Sandborn, 2019). Dr. Carver taught poor families how to manage and improve their soils creating household incomes and sustained farming. He challenged the exploration of the scientific method beyond textbooks (Ferrell, 2007). Barriers Dr. Carver and this project examined included translational science for the demonstration of process and economic viability of new technologies via scale-up of research from an academic environment, here CILEP ionic liquid-based technologies for biomass dissolution and the synthesis of materials from natural biopolymers. EO was a one year component of the project.

Provocative situational considerations and questions provided by the project leaders to the stakeholders and project participants promoted two-way dialog for individual and group engagement and thought. The research and EO team was asked not to lead the Partners, but allow for organic ideas and growth. The first task for the researcher and EO team was to provide a basic vocabulary and understanding of the project, the industry proposed, and how groups within a community might benefit, without pre-setting ideas or concepts. Select students and classrooms were then introduced to the concepts and in turn generated ideas and posters.

Community-Based Data Analysis and Outcomes The stepwise <u>process created</u> to establish a strategic planning template for the Community of Stakeholders and their use during the project focused on: (1) determination of community tools including EO and workforce development programs; (2) development of ideas useful in educating the community and public about biomass, biorefining, and green materials concepts to benefit the local community; (3) workshop focus areas; and a (4) poster-based competition for bio-projects, products, and processes utilizing biorefinery concepts (George Washington Carver new economy model) lending to localized entrepreneurial development.

Data revealed a robust industrial training program ripe for implementation of computer industrial control technology and simulation. Models and simulation aid in understanding real systems (Gray, 2016). A need was expressed to build on student interest in simulation starting from game engagement (Crawford, 2022), develop hands-on learning units, and internships including automation and control of new manufacturing technologies through industrial expansion. Rural student entrepreneurship in simulation process design would be an important first step in workforce preparation. The result would be to address existing underemployment due to restrictions on commute time and distance (Bonnal, 2009). Interest was also expressed in connecting the CILEP as a source for emerging medical research, graphene, and graphite and expanding industry linkages. The Chambers who were in favor of Industrial expansion supported assisting in any industrial, commercial, or business development.

Learning outcomes provided a conceptual understanding of the translational *Communities of Practice from research to demonstration and viability through local and regional Strategic Partner leadership networks*. Researchers continue to determine best options for community introduction and expansion along with scientific and engineering feasibility. Phase II is planned for seed testing and establishing EO programs linked to existing and future industry and business. The project is a step toward addressing disconnects that exists between targeted research demonstrations and viability with key community based stakeholders, investors, contractors, and innovative workforce preparation programs.

References (Literature Review)

Abbott-Jamieson, S., & Palma I. (2015). Natural and manmade disasters: Continuing nemesis for Louisiana, Mississippi, and Alabama fishing communities pre-and post-Katrina. *Marine Fisheries Review*, 77(3), 1-17.

Bonnal, B. Lira, C. & Addy, S. (2009). Underemployment and local employment dynamics: New evidence. *The Review of Regional Studies*, 39(3), 317–335.

Boykin, K., Wimberly, V., & Reed, M. (2019). Challenges to learning in rural settings for entrepreneurial advancement, *Online Learning Consortium*, https://onlinelearningconsortium.org/.

Constante, A., Pillay, S., Ning, H., & Vaidya, U., (2015). Utilization of algae blooms as a source of natural fibers for biocomposite materials: Study of morphology and mechanical performance of Lyngbya fibers. *Algal Research*, 12, 412-420, November.

Ferrell, J. S., (2007). George Washington Carver: A blazer of trails to a sustainable future; Land and power: Sustainable agriculture and African Americans. *Sustainable Agriculture Publications*, Waldorf, MD, 11-32.

Gray, J. & Rumpe, B., (2016). Models in simulation, *Journal of Software and Systems Modeling*, 15(3), 605-608, July.

Hernández-Cuevas, B. & Crawford, C., (2022). MTeacher: A gamified and physiological-based web application designed for machine learning education. N*ovel Design Approaches and Technologies,* 1*6th International Conference,* U*AHCI,* Held as Part of the 2*4th HCI International Conference,* H*CII Proceedings, Part I,* 435-445, July.

Jackson, H., (2007). Fishing for gold: The story of Alabama's catfish industry. *The Journal of Southern History*, 73(3), 745.

Mathis, M. & Baker, P., (2002). Assurance bonds: A tool for managing environmental costs in aquaculture. *Aquaculture Economics & Management*, 6(1-2).

Petterson, J., Glazier, E., Stanley, L., Jepson, M., Stevens, J., & Southerly, K., (2006). Identifying communities associated with the fishing industry in Alabama and Mississippi. *U.S. National Marine Fisheries Service; Impact Assessment.*

Roy, L., Whitis, G., & Walton, W., (2012). Demonstration of Blue Crab culture in inland low-salinity waters of West Alabama. *North American Journal of Aquaculture*, 74(4), October.

Sandborn, D., (2019). George Washington Carver's contributions to agriculture in the U.S.. *Michigan State University Extension*, February.

Upton, H., (2011). The deepwater horizon oil spill and the Gulf of Mexico fishing industry. *Congressional Research Service*, Library of Congress, 201, February 17.

Zavgorodnya, O., Shamshina, J., Berton, J., & Rogers, R., (2017). Translational research from academia to industry: Following the pathway of George Washington Carver, *Ionic Liquids: Current State and Future Directions,* 2, 17-33.

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Systematic literature review characterizing students' operational atomic structure knowledge

Emmanuel Echeverri-Jimenez, Morgan Balabanoff; Department of Chemistry (University of Louisville)*

Abstract Models are ubiquitous explanatory and predictive tools to make sense of phenomena. On one hand, students *think* with a model when they interpret the model to explain or predict an observation (i.e. operational modeling knowledge). On the other hand, students *think about* a model when they analyze how the model came to be, and identify its assumptions and limitations (i.e. epistemic modeling knowledge)[1,2]. Epistemic and operational knowledge are intertwined in a way that it is impossible to make sense of what a model is (epistemic) without understanding what it is for (operational) [1].

This work is part of a larger project aiming to identify correlations between students' epistemic and operational knowledge in the context of atomic structure. We chose atomic structure as our context because nature's behavior at the atomic level can be explained using multiple models with varying levels of sophistication. There is a clear progression in complexity between understanding the particulate nature of matter and utilizing quantum-mechanical concepts to explain sub-microscopic properties [3]. This work was guided by the following research questions:

1. Which intermediate curricular models have been reported in the progression towards the current expert-consensus model of atomic structure?

2. Which alternative conceptions have been found on each intermediate model, and what are the threshold concepts required for students to shift their modeling paradigm?

3. Which atomic structure levels of sophistication can be identified for a group of general chemistry students at the University of Louisville?

To address the first question, we considered atomic structure threshold concepts[4,5] to merge various atomic structure content progressions[6−11] into a framework composed of eight models ranging from notions preceding the particulate nature of matter to the use of wave functions to explain electron behavior. The framework is presented in detail in this talk, and it is the backbone for the identification of students' difficulties and alternative conceptions across multiple levels of sophistication of atomic structure models.

For the second question, we conducted a systematic literature review exploring atomic structure operational knowledge between 1972 and 2023, and compiling alternative conceptions identified by research groups worldwide. As part of the literature review, we utilized a bibliometric tool to identify research gaps and opportunities. The collected alternative conceptions were identified from students in the range between primary education-level to the postgraduate-level. These alternative conceptions were coded into atomic structure sophistication levels aiming to identify the types of difficulties students might encounter to progress through atomic structure models at each stage of their STEM education. Finally, the alternative conceptions were contrasted with the

Next Generation Science Standards' expectations for atomic structure operative knowledge[12] to compare current curricular expectations with students' difficulties at various educational levels.

For the third question, we conducted semi-structured interviews to identify general chemistry students' atomic structure conceptions and map their understanding on our atomic structure sophistication progression. Different stages of atomic structure knowledge were identified for students with different epistemic modeling knowledge. This work allowed us to create a framework to correlate students' current level of understanding with curricular expectations at different points of their STEM education. Having identified the typical alternative conceptions students face at each level, this framework is the foundation for the creation of an atomic structure learner-centered assessment that could help instructors identify their students' current level of understanding for atomic structure.

References

(1) Gouvea, J.; Passmore, C. 'Models of' versus 'Models For.' *Sci Educ (Dordr)* **2017**, *26* (1–2), 49–63. https://doi.org/10.1007/s11191-017-9884-4.
(2) Lazenby, K.; Stricker, A.; Brandriet, A.; Rupp, C. A.; Mauger-Sonnek, K.; Becker, N. M. Mapping Undergraduate Chemistry Students' Epistemic Ideas about Models and Modeling. *J Res Sci Teach* **2020**, *57* (5), 794–824. https://doi.org/10.1002/tea.21614.
(3) Justi, R.; Gilbert, J. History and Philosophy of Science through Models: Some Challenges in the Case of "the Atom." *Int J Sci Educ* **2000**, *22* (9), 993–1009. https://doi.org/10.1080/095006900416875.
(4) Park, E. J.; Light, G. Identifying Atomic Structure as a Threshold Concept: Student Mental Models and Troublesomeness. *Int J Sci Educ* **2009**, *31* (2), 233–258. https://doi.org/10.1080/09500690701675880.
(5) Budde, M.; Niedderer, H.; Scott, P.; Leach, J. "Electronium": A Quantum Atomic Teaching Model. *Phys Educ* **2002**, *37* (3), 303. https://doi.org/10.1088/0031-9120/37/3/303.
(6) Petri, J.; Niedderer, H. A Learning Pathway in High-school Level Quantum Atomic Physics. *Int J Sci Educ* **1998**, *20* (9), 1075–1088. https://doi.org/10.1080/0950069980200905.
(7) Taber, K. S. Conceptualizing Quanta: Illuminating the Ground State of Student Understanding of Atomic Orbitals. *Chem. Educ. Res. Pract.* **2002**, *3* (2), 145–158. https://doi.org/10.1039/B2RP90012B.(8) Stevens, S. Y.; Delgado, C.; Krajcik, J. S. Developing a Hypothetical Multi-Dimensional Learning Progression for the Nature of Matter. *J Res Sci Teach* **2009**, *47* (6), 687–715. https://doi.org/10.1002/tea.20324.
(9) Papageorgiou, G.; Markos, A.; Zarkadis, N. Students' Representations of the Atomic Structure – the Effect of Some Individual Differences in Particular Task Contexts. *Chemistry Education Research and Practice* **2016**, *17* (1), 209–219. https://doi.org/10.1039/C5RP00201J.
(10) Testa, I.; Capasso, G.; Colantonio, A.; Galano, S.; Marzoli, I.; Scotti di Uccio, U.; Trani, F.; Zappia, A. Development and Validation of a University Students' Progression in Learning Quantum Mechanics through Exploratory Factor Analysis and Rasch Analysis. *Int J Sci Educ* **2019**, *41* (3), 388–417. https://doi.org/10.1080/09500693.2018.1556414.
(11) Zarkadis, N.; Papageorgiou, G.; Stamovlasis, D. Studying the Consistency between and within the Student Mental Models for Atomic Structure. *Chemistry Education Research and Practice* **2017**, *18* (4), 893–902. https://doi.org/10.1039/C7RP00135E.

(12) National Research Council. *Next Generation Science Standards*; National Academies Press: Washington, D.C., 2013. https://doi.org/10.17226/18290.

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Locating Holes in the Leaky Pipeline: A Quantitative Investigation into Factors and Trends Within the STEM Attrition Crisis

Casandra Koevoets-Beach & Morgan Balabanoff (University of Louisville)

Abstract The challenge of retaining students in science, technology, engineering, and mathematics (STEM) majors is becoming increasingly evident. The President's Council of Advisors on Science and Technology (PCAST) has established this challenge as a national priority, calling for an additional million graduates in STEM majors over the next decade in order to meet societal needs in related fields (PCAST 2020). Approximately half of students who begin undergraduate education with the intent of pursuing a STEM major ultimately leave this projected path (Hayes et al 2009) and studies have shown that this student population leaving STEM is disproportionately comprised of women and underrepresented groups (Graham et al 2013; IUCPR 2019). This imbalance among those lost along the "leaky pipeline" (Blickenstaff, 2006) carrying students from high school through higher education and on to a job in STEM makes retaining more students in these majors a high priority.

By the third year in the undergraduate careers of first-time full-time students in the College of Arts & Sciences at the University of Louisville, less than 50% of the students who entered as first year students remain enrolled. This pattern holds for students majoring in biology, chemistry, geosciences, physics, and math. There is a diverse body of literature showing that retention in STEM is related to a strong sense of belonging, a growth mindset, interest and engagement in the sciences, and academic supports (Dweck 1999; Walton & Cohen 2007; Wentzel & Miele 2016).

To address this attrition crisis, we have developed a survey administered in introductory science courses to assess factors related to retention and the intention to persist among science majors in their first two years of college. The data obtained from this survey will be used to recommend changes at the instructor-, department-, college-, and university-level. This work seeks to measure students' opinions and perspectives regarding which tangible factors influence their determination to persist or decision to withdraw from a STEM education pathway. To measurably increase retention in STEM majors, the voices of this diverse body of students regarding their experiences and feelings as well as the existing institutional supports must be heard.

Research objectives for this quantitative study are: 1) Assess sense of belonging, mindset, perceptions of value and interest in science, and career intentions among science majors and non-majors,

2) Elicit students' perceptions of utility and accessibility of existing institutional resources developed to target STEM students' success, and

3) Combine these measures with institutional data on academic performance and analyze trends within individuals, majors, and demographic groups to determine if the outlined factors explain the variation among students' persistence in STEM majors.

This study utilizes paired T-tests of pre- and post-surveys and multiple linear regression analyses to predict STEM retention, focusing particularly on historically excluded groups. These analyses were employed to determine the combined impact of the factors outlined in RO1, perceptions of STEM resources, status as a science major or non-major, academic performance in the course, and demographic information on retention in STEM.

Presentation of this work includes expected targets for multi-level changes specifically centering students who are at highest risk of "leaking" out of the STEM major pipeline at our institution. Actionable instructor- and department-level recommendations based on the relationships identified between student identities, intentions, perceptions, and academic performance will be outlined.

References

Blickenstaff, J.C. (2006) *Women and science careers: leaky pipeline or gender filter?* Gender and Education. 17(4), 369-386

Dweck, C. S. (1999). *Self-theories: Their role in motivation, personality, and development.* New York: Psychology Press.

Graham, M.J., Frederick, J., Byars-Winston, A., Hunter, A., Handelsman, J. (2013). *Increasing the persistence of college students in STEM*. Science, 341, 1455-1456

Hayes, R.Q., Whalen, S.K., Cannon, B. (2009). *CSRDE STEM Retention Report*. Center for Institutional Data Exchange and Analysis: University of Oklahoma. Norman, OK

IUCPR Indiana University Center for Postsecondary Research (2013). *National Survey of Student Engagement: a fresh look at student engagement – annual results*. Bloomington, Indiana

PCAST, President's Council of Advisors on Science and Technology (2012). *Engage to excel: producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*.

Walton, G.M. & Cohen, G. L. (2007). *A question of belonging: Race, social fit, and achievement.* J. Pers. Soc. Psychol. 92, 82–96

Wentzel, K. R., & Miele, D. B. (2016). *Handbook of motivation at school*. Abingdon: Routledge.

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Technology-Based Programs for Preschoolers: How Does Technology-Based Interventions Close Gaps and Increase Kindergarten Readiness When Used in Pre-K Classrooms?

Erica Jones & Elizabeth MacTavish (University of Tennessee, Knoxville)

Introduction To prepare students better for the increased rigor and expectations now present upon kindergarten entry in Tennessee, there has been a push through legislation to focus efforts on increasing kindergarten readiness. This supports the view Borre et al. (2019) shared on how "Children who start kindergarten with a disadvantage in reading struggle to perform later as they progress in the school system, falling further behind their more literate peers over time" (p. 2). Pre-K programs such as the Tennessee Voluntary Pre-K program supports efforts in preparing students´ school readiness skills including both social and pre-academic skills with a focus on four year olds who qualify as at risk (Tennessee Voluntary Pre-K, 2023). As Pre-K is a voluntary grade and not a mandated entry point in the education system in the state of Tennessee, one obstacle for educators to increase kindergarten readiness revolves around how no interventions are present to aid in closing gaps with preschoolers, if they are present during the pre-kindergarten period.

The state of Tennessee sets guidelines and permissions for testing kindergarten school readiness for principals upon entry (State of Tennessee, 2022). This data along with other state and/or district level testing conducted in existing Pre-K programs can be used to monitor progression towards and assess kindergarten readiness. The purpose of this project is to determine if using a technology-based educational app applied as an intervention for preschoolers could increase kindergarten readiness. This quantitative action research project focuses on the use of technology-based educational apps as a means to provide intervention for preschoolers where no existing interventions are in place to increase kindergarten readiness. The participants are four year old preschoolers who attend a state funded voluntary preschool program providing preference to students from low-income households in a suburban East Tennessee school system.

The purpose of this study is to test if a technology-based intervention would increase participants´ kindergarten readiness. A higher growth score would indicate a higher level of readiness upon entry into a kindergarten setting. The data shows an increase for the experiment group as compared to the control group. Literature reflects much success in the early grades using one specific digital resource on a larger scale. A study by Thai & Ponciano (2016) supported how, "The more ABCmouse learning activities a student completed, the greater his or her kindergarten readiness score at the end of prekindergarten, indicating a reduction in the level of risk for school failure" (p. 5). All preschoolers in this study group were invited to add both Age of Learningś Math Academy and Reading Academy which is an intensive version of the recognizable ABCMouse learning app purchased by the school systemś voluntary Pre-K program for students to have at school and at home access. Progression and completion of learning activities were tracked by the preschool teacher for later analysis to determine if there was a correlation between usage of the intervention and growth on test data.

Research Questions The goal of this study is to answer the essential research question, how does technology-based curriculum/programs help close gaps and increase kindergarten readiness when used in preschool classrooms? Specifically, three questions guide the response in this study:

1. What preschool programs are currently in place?

2. What barriers are present that affect kindergarten readiness for students?

3. What technologies exist and are available to use in the preschool setting (used by students, teachers, and parents)?

Methodology and Timeline An adaptive app-based program was purchased from Age of Learning and initially implemented at the beginning of the 2022 - 2023 school year to act as a technology-based intervention to support literacy and numeracy skills. The support was offered to all students in two classes within a Tennessee state voluntary Pre-K program for use in class and at home.

<u>August/September 2022 (Intervention Options Researched, Selected, and Product Purchased)</u> In August/September of 2022, after researching available options, the MyMath Academy and MyReading Academy apps were purchased for all students in both Pre-K classrooms within the program. There were some struggles with initial setup for some parents, but most at least accessed or initiated the programs. The Age of Learning teacher portals allow teachers to monitor usage and account for time spent working on skills on the program for each student.

<u>School Year 2022 - 2023 (Implementation and Use); Fall 2023 (New Group Introduction and Transition on Access)</u> During the 2022 - 2023 school year, program teachers shared setup information and offered incentives for students who were accessing and practicing skills at home. For the 2023 - 2024 school year, after enrollment, new incoming students for both classrooms are set up and introduced to the intervention support. The company took feedback from customers and has converted the program to a web based versus the original app-based access. This should greatly improve access and impact usage.

Data Analysis & Results STAR Early Literacy scores were collected for year start to year end for previous school year groups not exposed to the intervention for comparison purposes comparing growth on tests to use as the control group. In late spring of 2023, year start to year end STAR Early Literacy scores were gathered for an experiment group to look at growth. Test score growth is a commonly used evaluation tool in education. Using SPSS, results were coded looking for correlations between test growth data and intervention usage. This technology intervention implementation suggests a slight, positive correlation between student use and activity on app as compared to growth on overall testing.The data available and analyzed so far shows a higher average/mean of growth from Fall to Spring STAR Early Literacy tests for the experiment group as compared to the control group where no intervention was present. The control group collectively gained a mean of a 21% increase in scores and the experimental group gained a mean of a 24% increase in scores from start to finish. Further time and testing will provide more data to analyze as intervention will be placed with new groups for 2023 - 2024 school groups with ease of access shifting.

Conclusion To ensure that students are best prepared for kindergarten and school as a whole, educators should take all necessary steps to increase kindergarten readiness upon entry. This comes down to Pre-K programs and families teaming up to meet the needs of this age group of students in Tennessee as the state does not currently provide extra support for voluntary Pre-K programs. With a slight, positive correlation between the added intervention, more research will guide this approach and its effectiveness in preparing future kindergarteners to start at their very best.

References

Borre, A.J., Bernhard, J., Bleiker, C., & Winsler, A. (2019, April 21). *Preschool Literacy Intervention for Low-Income, Ethnically Diverse Children: Effects of the Early Authors Program Through Kindergarten*. Taylor & Francis. Retrieved June 29, 2022, from https://www.tandfonline.com/doi/abs/10.1080/10824669.2019.1594818?needAccess=true&journalCode =hjsp20

State of Tennessee, State Board of Education. (2022, October). *Rules of The State Board of Education Chapter 0520-07-02 Non-Public School Approval Process*. Retrieved October 22, 2022, fromhttps://www.tn.gov/content/dam/tn/stateboardofeducation/documents/2022-sbe-meetings/october-28%2c -2022-sbe-meeting/10-28-22%20IV%20B%20Non-Public%20Schools%20Approval%20Process%20Ru le%200520-07-02%20Clean.pdf

Tennessee Voluntary Pre-K. Tennessee State Government -TN.gov. (n.d.). https://www.tn.gov/education/districts/early-learning/voluntary-pre-k.html

Thai, K.P. PhD. and Ponciano, L. PhD. (2016). "Improving Outcomes for At-Risk PreKindergarten and Kindergarten Students With a Digital Learning Resource," *Journal of Applied Research on Children: Informing Policy for Children at Risk*: Vol: 7: Iss. 2,. Article 8. Retrieved July 19, 2022, fromhttps://digitalcommons.library.tmc.edu/childrenatrisk/vol7/iss2/8/

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Using Questions to Support Student Sensemaking in an Integrated STEM Investigation

Lori Klukowski, R. Seth Jones, & Fonya C. Scott (Middle Tennessee State University)

Introduction Many of the conceptual frameworks used to describe integrated STEM are focused on the disciplinary knowledge and practices students need to know (Moore et al., 2020), either through the general interactions of STEM domains, (e.g. Mayes, 2019; Vasquez, 2014), or through the more specific interactions of disciplinary and cross-disciplinary concepts and practices, (e.g., Chalmers et al., 2017; Kelley & Knowles, 2016; Leung, 2020). These perspectives frame integrated STEM as an interaction among disciplinary knowledge and practices during a STEM activity. These framings, however, often do not describe how and when students interact with disciplinary knowledge and practices (Tytler et al., 2021). In contrast to a discipline-centered perspective, a student-centered perspective on integrated STEM describes how students interact with disciplinary thinking at different time scales (Tytler et al., 2021). Students experience disciplinary thinking: 1) during micro-level integration in the moment of the lesson, 2) during meso-level integration as the project or problem unfolds over the course of the unit, and 3) during macro-level integration as part of a developmental trajectory that occurs over months or years.

During micro-level integration, students are introduced to a real-world STEM problem and asked to draw upon disciplinary knowledge and practices of the different STEM domains to make sense of the problem. We want students to be able to use and understand the practices of the different STEM disciplines and learn how to productively reach for ideas and practices from other disciplines as they solve STEM problems (Tytler et al., 2021). To do this, students must engage in sensemaking to make connections among the phenomenon, disciplinary concepts and practices they are learning in school, and their prior experiences of the world (Benedict-Chambers et al., 2017; Li & Schoenfeld, 2019; Odden & Russ, 2019). When science teachers ask questions about disciplinary practices, concepts, and the phenomena or problem in the same lesson, they help students make sense of disciplinary practices (Benedict-Chambers et al., 2017; Colley & Windschitl, 2016; Fitzgerald & Palincsar, 2019). Little is known, however, about how science teachers' questioning strategies support students to reach for ideas and practices from other disciplines and to make sense of how those ideas might be relevant and fruitful during an integrated STEM investigation.

Here we report on a single case study of a science teacher facilitating a whole class discussion during an integrated STEM investigation about plant growth. Our analysis explores how he asked questions to help students draw upon ideas and practices from their science and mathematics classes as they made sense of their plant growth data. This study allows us to better understand new opportunities and challenges for science teacher questioning when engaging in cross-disciplinary teaching.

Research Context and Methods This study is part of a larger program of research investigating opportunities for collaboration of middle school mathematics and science teachers to teach statistical-based model inference. For this larger project, we videotaped sixth grade science teachers during an integrated STEM lesson in which students used ideas, i.e., measures of center, and practices, i.e., creating and critiquing data displays, developed through their mathematics curriculum to analyze a large data set of plant growth measurements, e.g., height, number of leaves, flowers, and buds, collected by the students in science class. Students were asked to create a data display that answered the question "What does a typical adult Wisconsin Fast Plant look like?" and to explain the evidence that supported their claim. They were guided in their explanations using the sentence stems: "A typical Wisconsin Fast Plant looks like…" and "I know this because…" In this preliminary study, we focus on the questions of Mr. Houston to understand how he supported his students to make sense of their measurement data.

In our analysis, we first coded the video recording using MaxQDA to indicate which utterances by the teachers were questions. Once we established segments of the recording as questions, we used categories developed by Benedict-Chambers et al., 2017 to code each question. We then used these codes to characterize different patterns of questioning that provided students opportunities to make connections among the phenomenon their data represents and disciplinary concepts and practices. Here we describe one pattern of Mr. Houston's questioning that provided an opportunity for students to make sense of their plant growth measurements.

Findings

Student Sense Making

In this excerpt, Mr. Houston asked the students to provide an explanation for the difference between their claims about an attribute of a typical plant and a mathematically calculated measure of center, the mean. He then used questions about mathematical concepts to support the development of their explanation.

Mr. Houston: (10:04, second period) "Actually, my average falls in the three range and no one said three, right? [*Students had previously claimed a typical plant had either five or ten seed pods. A data display, Figure 1, is projected in front of the class*] But the average, if we used mean, is three, right? Why is our average three? Why do you think our average is so much lower than you thought a typical one [number of seed pods] would be?

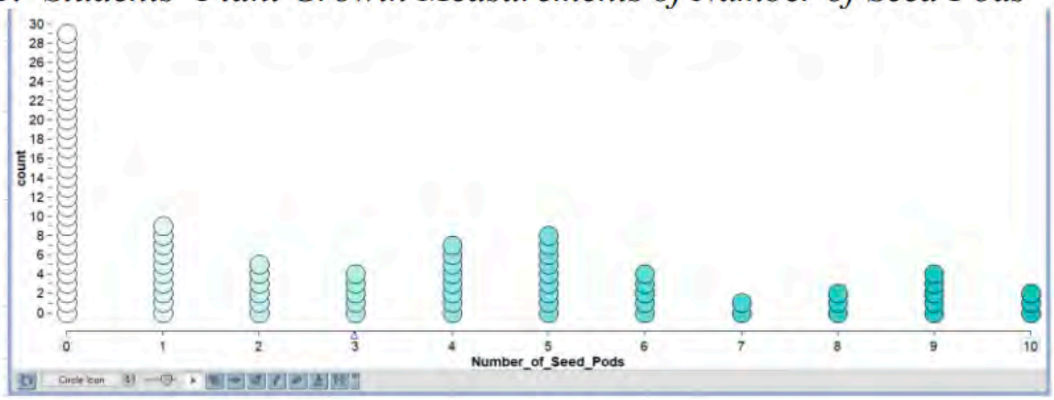
James: Because there's so many zeroes. Mr. Houston: Because there's so many zeroes, there's so many plants that had zeroes, but there's a lot of other plants that had other numbers too. Right? So, maybe, average might not be the best for this. What would you say another way we could look at this? Another measure of center? Median? Brian: Yeah, median. Mr. Houston: Median. Where did our median pop up? Brian: Oh, on two.

Mr. Houston: Oh, it did. So, our median was actually on two here. Right? And then the mode, if we show the mode, the most often is going to be zero, right?

Students: Yeah, mmmhmm.

Mr. Houston: Yeah, we knew that. We threw out the zeroes on the buds, right? And on the plant height actually the zeroes are thrown out, so, so, it depends on, again, it depends on which one you choose.

Figure 1: Students' Plant Growth Measurements of Number of Seed Pods



Discussion Sense making begins by trying to explain a gap or inconsistency in one's knowledge (Odden & Russ, 2019). By asking students to explain why the mean was so different from their initial claims, Mr. Houston explicitly highlighted a gap between what his students claimed was the typical number of seed pods and the mathematical measures of center. This question provided an opportunity for sensemaking and allowed the students to develop an explanation, i.e., "there's so many zeroes," for why the mean was lower than what they expected.

Previous literature has suggested the pattern of questioning is important in the development of students' sensemaking explanations, (e.g., Benedict-Chambers, 2017; Colley & Windschitl, 2016). These early findings provide insight into how to assist science teachers in providing opportunities for student sensemaking in integrated STEM investigations.

Literature Cited

Benedict-Chambers, A., Kademian, S. M., Davis, E. A., & Palincsar, A. S. (2017). Guiding students towards sensemaking: Teacher questions focused on integrating scientific practices with science content. *International Journal of Science Education*, *39*(15), 1977-2001.

Chalmers, C., Carter, M., Cooper, T., & Nason, R. (2017). Implementing "big ideas" to advance the teaching and learning of science, technology, engineering, and mathematics (STEM). *International Journal of Science and Mathematics Education*, *15*, 25-43.

Colley, C., & Windschitl, M. (2016). Rigor in elementary science students' discourse: The role of responsiveness and supportive conditions for talk. *Science Education*, *100*(6), 1009-1038.

Fitzgerald, M. S., & Palincsar, A. S. (2019). Teaching practices that support student sensemaking across grades and disciplines: A conceptual review. *Review of Research in Education*, *43*(1), 227-248.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM education*, *3*, 1-11.

Leung, A. (2020). Boundary crossing pedagogy in STEM education. *International Journal of STEM Education*, *7*(1), 1-11.

Li, Y., & Schoenfeld, A. H. (2019). Problematizing teaching and learning mathematics as "given" in STEM education. *International journal of STEM education*, *6*(1), 1-13.

Mayes, R. (2019). Quantitative reasoning and its role in interdisciplinarity. In B. Doig, J. Williams, D. Swanson, R. Borromeo Ferri, and P. Drake (Eds), *Interdisciplinary mathematics education: The state of the art and beyond*, (pp. 113-133). Springer.

Moore, T. J., Johnston, A. C., & Glancy, A. W. (2020). STEM Integration. In C.C. Johnson, M.J. Mohr-Schroeder, T.J. Moore, and L.D. English (Eds), *Handbook of research on STEM education,* (pp. 3-16). Routledge.

Odden, T. O. B., & Russ, R. S. (2019). Defining sensemaking: Bringing clarity to a fragmented theoretical construct. *Science Education*, *103*(1), 187-205.

Tytler, R., Prain, V., & Hobbs, L. (2021). Rethinking disciplinary links in interdisciplinary STEM learning: A temporal model. *Research in Science Education*, *51*, 269-287.

Vasquez, J. A. (2015). STEM–Beyond the Acronym. *Educational Leadership*, *72*(4), 10-15.

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POSTER PRESENTATIONS

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A Conversation with BlueBot: Promoting STEM Education via Chatbots

Zain Al-Saad & Tisha Gaines (Belmont University)

Abstract Within the past decade, chatbots, along with the use of artificial intelligence (AI), have become more advanced in terms of data size and natural language processing (NLP) . A chatbot is a program which receives input from a user, and outputs the requested information. They have many flexible use cases, ranging from industrial support systems, healthcare and even education. With the use of NLP, chatbots are able to understand and even mimic human conversation. This empirical study will analyze a Java-based scripted chatbot intended to achieve a human-like conversation by nesting various predefined topics to promote STEM education. Using a scripted chatbot with predefined input sets and output text we observe interactions of student users to analyze the level of engagement. Furthermore, the chatbot implemented in this study will be able to express emotions through an array of images, creating a more interactive and human-like conversation exchange.

Introduction One of the defining advances in artificial intelligence (AI) in the past decade is the rapid development of chatbots[1[. Chatbots, by definition, is a program that receives input from a user, and outputs the requested information. A central objective of chatbots has many use cases to achieve the output result, with recent developments integrating machine learning (ML) [2]. A common use case of chatbots among beginner computer scientists is through a set of predefined questions and responses, in which the database is static until manually updated by the developer [3]. This is known as a scripted chatbot, ML is not used in this case. In some other cases, ML is used to corroborate the user's input to a predefined topic/question, which then provides a predefined answer [4]. Apple's voice assistant, Siri, was built on this model. In Siri's use case, machine learning (ML) was used to interpret the user's intentions, call a search engine's API to retrieve information and paraphrase the result to the user. To ensure the accuracy of determining the user's intent, a large database of phrases was used (e.g. In Figure 1, the phrase "fun for the kids" was correlated to "family events", a predefined topic). A major recent development in ML which this paper will be focusing on is a chatbot's ability to mimic informal human conversation [4]. BlueBot (seen in Figure 2), a GUI Java-based scripted chatbot, aims to achieve this, mimicking ML by interpreting the user's input to achieve a true feeling of a human conversation [5]. The purpose of this case study is to analyze if a realistic, human conversation can be achieved through a scripted chatbot to enhance students levels of engagement with STEM topics.

The data obtained in this study assisted in evaluating our research question's goals seen below.

1. Can a Chatbot promote student engagement with STEM topics?

2. What level of student engagement can be achieved with Chatbot interactions?

3. Are scripted Chatbots effective in enhancing students level of engagement with STEM topics?

Figure 1: Siri's original application
Here, the user's intent is labeled green, while the preset responses are labeled black.

Figure 2: BlueBot.

Here, a user has a conversation with a chatbot friend. Depending on the input, the robot's face has the ability to display various emotions.

References:

1. Caldarini G, Jaf S, McGarry K. A Literature Survey of Recent Advances in Chatbots. *Information*. 2022; 13(1):41. https://doi.org/10.3390/info13010041

2. Kooli C. Chatbots in Education and Research: A Critical Examination of Ethical Implications and Solutions. *Sustainability*. 2023; 15(7):5614. https://doi.org/10.3390/su15075614

3. Mendoza S, Sánchez-Adame LM, Urquiza-Yllescas JF, González-Beltrán BA, Decouchant D. A Model to Develop Chatbots for Assisting the Teaching and Learning Process. *Sensors (Basel)*. 2022;22(15):5532. Published 2022 Jul 25. doi:10.3390/s22155532

4. Yin, J., Goh, T.-T., Yang, B., & Xiaobin, Y. (2021). Conversation Technology With Micro-Learning: The Impact of Chatbot-Based Learning on Students' Learning Motivation and Performance. Journal of Educational Computing Research, 59(1), 154–177. https://doi.org/10.1177/0735633120952067

5. Noorhan Abbas, Jenni Whitfield, Eric Atwell, Helen Bowman, Thomas Pickard & Aisha Walker (2022) Online chat and chatbots to enhance mature student engagement in higher education, International Journal of Lifelong Education, 41:3, 308-326, DOI: 10.1080/02601370.2022.2066213

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Analysis of Demographic and Experiential Interactions in Quantitative General Education USAFA Courses and their Impact on STEM Attrition

Wilson González-Espada (Morehead State University), Capt. Scott Alsid, Maj. Daniel O'Keefe, Lt. Col. David Meier, & Maj. Christopher M. Francis (United States Air Force Academy)

Introduction Science, technology, mathematics, and engineering (STEM) attrition occurs when undergraduates who are STEM-interested or originally declared STEM majors move away from these fields by switching majors or dropping out of college. Recently, several studies have examined STEM attrition at civilian universities (Brewer et al., 2021; Chen, 2015, 2013; Malcom & Feder, 2016; Romash, 2019; Seymour & Hewitt, 1997; Seymour & Hunter, 2019).

STEM attrition is also experienced by cadets enrolled in military postsecondary institutions. A group of researchers at the U.S. Air Force Academy (USAFA) have examined this phenomenon as an avenue for identifying and minimizing cadets departing from STEM majors. However, questions remain about the relative impact of responsible academic and nonacademic factors as perceived by STEM departers (Dwyer et al., 2020; O'Keefe et al., 2023, 2022).

Research Questions This study closely examined the academic and non-academic factors linked to STEM attrition from the perspective of USAFA cadets in the Humanities and Social Sciences Divisions (HSSD), where the non-STEM majors are offered. This group was selected because previous research demonstrated that many of these cadets were "STEM-interested" at some point in time and many originally were part of the Basic Sciences and Engineering Divisions (BSED). The research questions considered were:

1. To what extent were cadets from HSSD "STEM-interested" in high school or as undeclared freshmen, or originally choose STEM majors in BSED?

2. How did cadets rate the influence of conceptual understanding, final grades, classroom experience, time and effort invested in STEM coursework, and instructor pacing in general education STEM classes in their decision to switch to non-STEM majors?

3. Is there an association between the reported influence of academic and non-academic factors in the cadets' decision to switch to non-STEM majors and demographic variables?

4. What were the most common recommendations that cadets proposed to attract and retain STEM-interested cadets?

Methodology The sample size was 187 cadets for certain analyses and 136 cadets for others, depending on the research question. A survey included:

<u>1. Screening questions</u> asking whether the cadets had planned to major in STEM as high school students or as undeclared cadets and whether they declared a STEM major before switching to a non-STEM major.

<u>2. Ranking questions,</u> cadets ranked fifteen statements describing reasons that could have influenced their decision to ultimately declare a non-STEM major, from "1" to represent a factor

that was not influential at all or not true to them, to "10" to represent a factor that was very influential or very true to the cadets during the decision-making process to major in nonSTEM disciplines. The statements referenced five general education STEM classes (Calculus I 2 & II, Aeronautics Fundamentals, Mechanics Fundamentals, General Chemistry I, and Astronautics Fundamentals), subdivided into categories of classroom experience, understanding of the content covered in class, and final course grade. Another ranking task included factors not tied in with specific classes and included instructor pacing and invested time and effort.

3. Open-ended question, where cadets were asked to provide USAFA with three recommendations that could be implemented to attract undecided cadets to declare a STEM major.

4. Demographic questions, these asked information about the participants' sex, race or ethnicity, Preparatory Academy attendance, high school of origin, average annual family income, and whether participants were first-generation college graduates.

Data analysis For the quantitative data ranking potential influences in declaring a non-STEM major, Kruskal Wallis statistics were reported when comparing three or more groups. Mann-Whitney Z statistics were reported for pairwise comparisons and post hoc analysis. Because of the exploratory nature of the study, minimum statistical significance was assigned a probability (p) value of 0.05 or less to balance the risks of Types I and II errors. The open responses were manually analyzed using thematic analysis (Braun & Clark, 2012; Creswell and Creswell, 2018). Representative quotes were selected to present the themes in the cadets' voices (Boyatzis, 1998; Saldaña, 2021).

Conclusion About three-fourths of the participants reported interest in STEM (high school and during their first year), and about two-thirds of them even originally declared STEM majors. Only 35 cadets (19% of the participants) declared non-STEM majors right away, without initially declaring a STEM major or expressing any interest in STEM majors in high school or as undeclared cadets.

The three most impactful factors related to STEM attrition (> 5.00 on the impact scale) included the instructors' accelerated pacing of instruction, the limitations of time and effort due to the workload, and the classroom experience in Calculus I & II. Two of these factors, instructor pacing and excessive workload, also emerged in the qualitative analysis. Moderate but lower impacts were identified in classroom experiences in General Chemistry I, classroom experiences in Mechanics Fundamentals, conceptual understanding and final grade in Mechanics Fundamentals, conceptual understanding and final grade in Calculus I & II, and final grade in General Chemistry I.

The analysis revealed push factors disparities between lower-income vs. higher-income families, cadets who attended vs. did not attend Preparatory schools, and cadets from minority backgrounds vs. Caucasian cadets. Cadets provided numerous ideas to prevent STEM attrition, including modifying the classes that are part of the general education STEM program, advising freshmen about the benefits or perks of majoring in STEM, reducing workload for STEM majors, attracting and maintaining high-quality instructors, improving departmental culture, expanding research opportunities, and balancing the GPA for STEM and non-STEM majors to avoid disadvantaging STEM majors in USAFA benefits or perks. In practice, some of their recommendations are more feasible than others in the context of the legal and curricular realities of USAFA. These findings align with previous studies that point to STEM attrition as an ongoing, concerning challenge for the U.S. Department of Defense, particularly at USAFA. 3

References

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. SAGE Publications.

Braun, V., & Clarke, V. (2012). *Thematic analysis*. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), APA handbook of research methods in psychology, Vol. 2. Research designs: Quantitative, qualitative, neuropsychological, and biological (pp. 57–71). American Psychological Association.

Brewer, H. E., González-Espada, W. J., & Boram, R. (2021). Student retention in quantitative STEM majors: Science teachers and college students' perceptions of push and pull factors. J*ournal of the Kentucky Academy of Science,* 82(1), 1-12.

Chen, X. (2015). STEM attrition among high-performing college students in the United States: Scope and potential causes. *Journal of Technology and Science Education*, 5(1), 41-59.

Chen, X. & Soldner, M. (2013). *STEM attrition: College students' paths into and out of STEM fields*. NCES 2014-001). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Creswell, J. W. and Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mix methods approaches*. Los Angeles, CA: Sage Publications.

Dwyer, J. H., González-Espada, W. J., de la Harpe, K., & Meier, D. C. (2020). Factors associated with students graduating with STEM degrees at a military academy: Improving success by identifying early obstacles. J*ournal of College Science Teaching,* 50(1), 20-27.

Malcom, S. & Feder, M. (2016). *Barriers and opportunities for 2-year and 4-year STEM degrees: Systemic change to support students' diverse pathways*. Washington, DC: National Academies of Sciences, Engineering, and Medicine, National Academies Press.

O' Keefe, D. S., González-Espada, W. J., and Meier, D. (2023) Beyond STEM attrition: Quantifying the flow of U.S. Air Force Academy cadets between academic majors to improve STEM persistence. J*ournal of Military Learning,*7(2), 3-25.

O' Keefe, D. S., Meier, D., Valentine-Rodríguez, J., Belcher, L. T., & González-Espada, W. (2022). A mixed methods analysis of STEM major attrition at the U.S. Air Force Academy. J*ournal of Military Learning,* 6(1), 15-38.

Romash, Z. M. (2019). *Leaving STEM: An examination of the STEM to non-STEM major change and how the STEM curriculum relates to academic achievement in non-STEM fields* [Doctoral Dissertation, Seton Hall University, NJ.]

Saldaña, J. (2021). T*he coding manual for qualitative researchers.* SAGE Publications.
Seymour, E. & Hewitt, N. M. (1997). T*alking about leaving.* Boulder, CO: Westview Press.
Seymour, E. & Hunter A. B. (2019). T*alking about leaving revisited: Persistence, relocation, and loss in undergraduate STEM education. S*witzerland, Springer Nature.

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Analysis of Performance on the Praxis Biology Content Knowledge Test at the Category-level

Andrea Reeder & Heather Green (Middle Tennessee State University)

Abstract The importance of highly qualified teachers is greater than ever. Prior to the COVID-19 pandemic, teacher shortages were of high concern, especially in STEM (Podolsky et al., 2016; Sutcher et al., 2019). Since the start of the pandemic in 2020, these shortages have been exacerbated with a 9% decrease in K12 teachers, a trend that has not improved since then (Bleiberg & Kraft, 2022; Ngyuen et al.,2022). In a recent survey by the National Education Association (NEA), 55% of teachers are thinking of leaving the profession earlier than they had originally planned (Walker, 2022). In addition, to these issues, school administrators do not consistently hire teachers based on credentials that research shows improves the likelihood of student achievement (Howard & Mays, 2020).

Qualified teachers are major contributors to student success (Darling-Hammond, 2000). Three teacher credentials that have a positive effect on student achievement are a bachelor's degree from an accredited university, standard state certification, and national board certification (Clotfelter et al., 2010). Subject-specific content knowledge is, therefore, a key component to the status of teacher qualification. What is currently unknown are the strengths and weaknesses of pre-service teacher content knowledge. Studies of pre-service teacher content weaknesses cover the range of biology topics taught in secondary introductory biology classes. Preservice teachers can have issues in ecology (Putri, 2021; Butler et al, 2014), diffusion and osmosis (Ziherl & Torkar, 2022), genetics (Entobro & Benjoko, 2017), cell biology (Suwono et al, 2019), cellular respiration (Saat et al, 2016), and evolution (Hartelt et al, 2022; Yates & Marek,2014). None of these studies focus on the strengths of candidates. With 46 states and the District of Columbia requiring Praxis tests to confirm a licensure candidate's content knowledge (McMahon, 2023), performance on a Praxis exam is important in understanding teacher content knowledge. Because Praxis cut scores vary by state, even when a teacher has a passing score on a Praxis test, they may still have some areas of content knowledge that are stronger than others (McMahon, 2023).

In this research, we will examine scores on the Praxis Biology Content Knowledge Test 5235 in the years 2006-2015. The five content category areas of the Biology Praxis are: history and nature of science, molecular and cellular biology, genetics and evolution, diversity of life and organismal biology, ecology, and social perspectives (Educational Testing Service, 2018). Understanding teachers' assets and needs regarding content can affect decision making about the format and content of biology teacher professional development.

Research Questions The purpose of this study is to better understand pre-service teachers' biology content knowledge. 1. In what categories are pre-service teacher strengths and weaknesses are in terms of their biology content knowledge?
2. Are there trends in category content knowledge in terms of candidate demographics?

References

Bleiberg, J. F., & Kraft, M. A. (2023). What happened to the K–12 education labor market during COVID? the acute need for better data systems. *Education Finance and Policy*, *18*(1), 156–172. https://doi.org/10.1162/edfp_a_00391

Butler, J., Mooney Simmie, G., & O'Grady, A. (2014). An investigation into the prevalence of ecological misconceptions in upper secondary students and implications for pre-service teacher education. *European Journal of Teacher Education*, *38*(3), 300–319. https://doi.org/10.1080/02619768.2014.943394

Darling-Hammond, L. (2000). Teacher quality and student achievement. *Education Policy Analysis Archives*, *8*, 1. https://doi.org/10.14507/epaa.v8n1.2000

Educational Testing Service. (2018). *Biology: Content knowledge study companion - ETS*. ets.org. https://www.ets.org/pdfs/praxis/5235.pdf

Etobro, A. B., & Banjoko, S. O. (2017). Misconceptions of genetics concepts among pre-service teachers. *Global Journal of Educational Research*, *16*(2), 121. https://doi.org/10.4314/gjedr.v16i2.6

Hartelt, T., Martens, H., & Minkley, N. (2022). Teachers' ability to diagnose and deal with alternative student conceptions of evolution. *Science Education*, *106*(3), 706–738. https://doi.org/10.1002/sce.21705

McMahon, B. (2023). *Which states do not require praxis*. Praxisexam.org. https://praxisexam.org/praxis/which-states-do-not-require-praxis/

Nguyen, Tuan D., Chanh B. Lam, and Paul Bruno. (2022). Is there a national teacher shortage? A systematic examination of reports of teacher shortages in the United States. (EdWorkingPaper: 22-631). Retrieved from Annenberg Institute at Brown University: https://doi.org/10.26300/76eq-hj32

Podolsky, A., Kini, T., Bishop, J., & Darling-Hammond, L. (2016). Solving the Teacher Shortage: How to Attract and Retain Excellent Educators. Palo Alto, CA: Learning Policy Institute.

Putri, A. N. (2021). The identification of preservice biology teacher's misconceptions on the concept of mangrove ecology using the certainty of response index (CRI). *Journal of Physics: Conference Series*, *1940*(1), 012124. https://doi.org/10.1088/1742- 6596/1940/1/012124

Saat, R. M., Mohd Fadzil, H., Abd. Aziz, N. A., Haron, K., Rashid, K. A., & Shamsuar, N. R. (2016). Development of an online three-tier diagnostic test to assess pre-university students' understanding of cellular respiration. *Journal of Baltic Science Education*, *15*(4), 532–546. https://doi.org/10.33225/jbse/16.15.532

Sutcher, L., Darling-Hammond, L., & Carver-Thomas, D. (2019). Understanding teacher shortages: An analysis of teacher supply and demand in the United States. Education Policy Analysis Archives, 27(35). http://dx.doi.org/10.14507/epaa.27.3696

Suwono, H., Prasetyo, T. I., Lestari, U., Lukiati, B., Fachrunnisa, R., Kusairi, S., Saefi, M., Fauzi, A., & Atho'Illah, M. F. (2019). Cell Biology Diagnostic Test (CBD-test) portrays pre-service teacher misconceptions about biology cell. *Journal of Biological Education*, *55*(1), 82–105. https://doi.org/10.1080/00219266.2019.1643765

Walker, T. (2022, February 1). *Survey: Alarming number of educators may soon leave the profession*. NEA. https://www.nea.org/nea-today/all-news-articles/survey-alarming- number-educators-may-soon-leave-profession

Yates, T. B., & Marek, E. A. (2014). Teachers teaching misconceptions: A study of factors contributing to High School Biology Students' acquisition of biological evolution-related misconceptions. *Evolution: Education and Outreach*, *7*(1). https://doi.org/10.1186/s12052- 014-0007-2

Ziherl, S., & Torkar, G. (2022). Foundations matter: Pre-service teachers' understanding of osmosis and diffusion in relation to their formal science education backgrounds. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(6). https://doi.org/10.29333/ejmste/12041

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Analyzing End-of-chapter Questions and In-chapter Sample Problems in General Chemistry Textbooks for Diversity of Real-world Applications and Cultural Perspectives,

Jennifer Stockdale & Kathryn Hosbein (Middle Tennessee State University)

Introduction For decades, education researchers have challenged educators to recognize the value of introducing a diversity of cultural relevance in pedagogy, curriculum, and other course materials (Ladson-Billings, 2014). This call stems from the realization that a diverse and culturally relevant educational approach fosters a more inclusive learning environment that can aid in student persistence. This is particularly relevant in STEM fields, where the retention of marginalized groups is disproportionately low (Riegle-Crumb et al., 2019). To integrate more culturally relevant material in classrooms, it is necessary to examine the diversity of real-world applications and the cultural perspectives represented in current course materials.

One course material that has not been examined for a diversity of cultural relevance is the general chemistry textbook. Textbooks help to create an environment that welcomes and supports students in their journey to learn the complex topics introduced in chemistry (Salloum, 2021). Moreover, general chemistry textbooks often serve as a guideline for generating curriculum, formulating assignments, and creating assessment tools (Dávila & Talanquer, 2010). As such, textbook questions and problems play a pivotal role in assessing students' comprehension of the subject matter (Dávila & Talanquer, 2010). Oftentimes, science and math textbooks are limited in their views of historical perspectives of science (usually dominated by male Eurocentric representations) (Chacón-Díaz, 2022). Thus, we have designed a study to understand the current diversity of real-world applications and cultural perspectives in commonly used General Chemistry textbooks. Making sure textbooks include culturally relevant and diverse real-world applications in the questions and problems would help to ensure that all students, regardless of cultural backgrounds, are represented. This representation in textbooks could help students to develop a positive science identity by feeling seen *and* therefore encourage them to remain engaged in the process of learning chemistry. This representation could also help with positive science identity development by emboldening students of diverse backgrounds to believe that they too can *lear*n chemistry and potentially inspire them to further their education in the field of chemistry (Hosbein & Barbera, 2020). After all, chemistry is a universal discipline that affects all peoples of every background, ethnicity, and culture (Chacón-Díaz, 2022).

Qualitative analyses of science textbooks for historical perspectives and diversity representation using various theoretical frameworks have been completed by science education researchers in the past (Chacón-Díaz, 2022; Salloum, 2021). The goal of such studies is to magnify the deficiency in representation of cultures that are outside of the Eurocentric majority. Though research of textbooks has been done, the persistent lack of diversity in textbooks shows that there is a need for further study in an effort to generate change. Furthermore, at present,

there have been no studies that analyze the content of General Chemistry textbook problems and questions relative to a diversity of real-world applications and cultural perspectives.

Research Questions The purpose of this research study is to assess the diversity of real-world applications and cultural perspectives of end-of-chapter and in-chapter sample problems in commonly used General Chemistry textbooks. Therefore, the research questions in this study are:

1) What real-world applications are represented within two modern chemistry textbooks?
2) What cultural perspectives are used to frame real-world applications within two modern chemistry textbooks?

Methodology and Timeline Two commonly used General Chemistry textbooks were used for this analysis. The textbooks selected will be among those which are currently used in the United States so as to represent curriculum taught in U.S. institutions. A comprehensive review of end-of-chapter and in-chapter sample problems in the selected textbooks was conducted. This assessment will involve inductive qualitative coding to determine themes among real-world examples used as well as cultural perspectives framing the examples. The diversity of real-world application examples and cultural perspectives will be categorized using specific codes describing different patterns in representation. This methodology will allow for analysis of the cultural relevancy and diversity of one aspect of general chemistry textbooks. Preliminary results from this analysis will be presented within this poster presentation.

Conclusion Through this study, we hope to add to the continued efforts to create a more inclusive science education experience through course materials like textbooks.

References

Chacón-Díaz, L. B. (2022). A Textbook Analysis to Uncover the Hidden Contributors of Science and Mathematics. Sc*ience & Education,* 31*(1*), 193–211. Htps://doi.org/10.1007/s11191- 021-00246-7

Dávila, K., & Talanquer, V. (2010). Classifying End-of-Chapter Questions and Problems for Selected General Chemistry Textbooks Used in the United States. J*ournal of Chemical Education,* 87*(*1), 97–101. ttps://doi.org/10.1021/ed8000232

Hosbein, K. N., & Barbera, J. (2020). Alignment of theoretically grounded constructs for the measurement of science and chemistry identity. *Chemistry Education Research and Practice*, *21*(1), Article 1. https://doi.org/10.1039/C9RP00193J

Ladson-Billings, G. (2014). Culturally Relevant Pedagogy 2.0: A.k.a. the Remix. *Harvard Educational Review*, *84*(1), Article 1. https://doi.org/10.17763/haer.84.1.p2rj131485484751

Riegle-Crumb, C., King, B., & Irizarry, Y. (2019). Does STEM Stand Out? Examining Racial/Ethnic Gaps in Persistence Across Postsecondary Fields. *Educational Researcher*, *48*(3), Article 3. https://doi.org/10.3102/0013189X19831006

Salloum, S. (2021). Intertextuality in science textbooks: Implications for diverse students' learning. *International Journal of Science Education*, *43*(17), 2814–2842. https://doi.org/10.1080/09500693.2021.1992530

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Computing Education in Ghana: A Preliminary Investigation

Crystal Davis & Ryan A. Nivens (East Tennessee State University)

Background Computer programming and computer literacy are gaining more attention because of need for these skills in the future workplace (Grover & Pea, 2013). The founder of Microsoft Research said, "Computing is an essential tool for discovery and advancement in virtually every field of science. And as we move forward, computing holds the key to progress in almost every human endeavor" (Rashid, 2008, p. 33). Over the years, many studies have documented the benefits of computer programming for children in grades K-6 (for example, Clements, 1985; Fessakis, Gouli, & Mayroudi, 2013; Kazakoff & Bers, 2012; Lin, 2015). However, most of the research studies are based in U.S. classrooms whereas the country of Ghana follows the British system of education. Personal experience in Ghana anecdotally reveals a tendency to emphasize computing education for male students. This experience was followed with a brief investigation to the prevalence of females in studies of computing education in African countries which is the basis for the proposed poster.

Significance of the Research Emphasis on research involving underserved and excluded populations has taken a front seat in conversations in the past decade. Research on African females in Ghana show that access is not equal (Akyeampong et al., 2007). Additionally, the impact on females across the school years of K-12 only exacerbates the problems associated with limited access (Takyi et al., 2021). What is not well known is the scope of computing education among females in Ghana, and that is what we have seen as a need to start with a comprehensive, focused literature review for an eventual thesis research project.

Research questions This research is presented to address the questions: What is the current state of computing education in West African countries? To what extent has Ghana been studied in computing education? How representative are female students aged 15-22 in computing education in Ghana?

Preliminary analysis Method: Google Scholar was queried using various search terms from "ghana female education" and "K-12 Computing Education in Africa Ghana". These queries have shown us a broad view from which to narrow.

References

Akyeampong, K., Djangmah, J., Oduro, A., Seidu, A., & Hunt, F. (2007). *Access to basic education in Ghana: the evidence and the issues — country analytic report*. UK: CREATE, University of Sussex. Retrieved from https://files.eric.ed.gov/fulltext/ED508809.pdf

Clements, D. H. (1985). Research on logo in education: Is the turtle slow but steady, or not even in the race?. *Computers in the Schools*, 2, 55-71.

Fessakis, G., Gouli, E., & Mavroudi, E. (2013). Problem solving by 5–6 years old kindergarten children in a computer programming environment: A case study. *Computers & Education*, 63, 87-97.

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher*, 42(1), 38-43.

Kazakoff, E., & Bers, M. (2012). Programming in a robotics context in the kindergarten classroom: The impact on sequencing skills. *Journal of Educational Multimedia and Hypermedia*, 21(4), 371-391.

Lin, V. J. (2015). *Computational Thinking and Technology Toys*. Honors Thesis: Wellesley.
Rashid, R. (2008). Image crisis: Inspiring a new generation of computer scientists.

Communications of the ACM, 51(7), 33-34.

Takyi, S. A., Amponsah, O., Asibey, M. O., & Ayambire, R. A. (2021). An overview of Ghana's educational system and its implication for educational equity. *International Journal of Leadership in Education*, 24(2), 157–182. https://doi.org/10.1080/13603124.2019.1613565

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Examining Students' Epistemic Knowledge of Atomic Structure Models in Chemistry

Salawat Lateef (University of Louisville), Emmanuel E. Jimenez, & Morgan Balabanoff

Abstract Using and interacting with science models is a central science practice, particularly in chemistry in the context of atomic structure models. Students' epistemological knowledge of modeling influences their understanding and application of science models (Lazenby et al., 2020). Another study revealed that students are inclined towards using observable ideas to explain scientific models and could not visualize unseen mechanism (Cheng & Lin, 2015). However, studies have shown that epistemic knowledge is context dependent (Nasir et al., 2021; Schwarz et al., 2022; Schwarz & White, 2005). Atomic structure and the nature of matter are fundamental elements in chemistry that are further built on across STEM courses. The conceptualization of atomic structure can be challenging because it relies on models to illustrate something we cannot directly observe. In this context, considering how students think about scientific models is a way to support student understanding.

Students ranging from general chemistry to physical chemistry struggle to explain and apply atomic structure (Papageorgiou et al., 2016; Roche Allred & Bretz, 2019; Zarkadis et al., 2017). Harrison and Treagust (1996) conducted a study to explore students' mental models of atoms and molecules and they found that students preferred models that are discrete and concrete. This also aligns the findings that students strongly used ideas from classical mechanics to interpret the electron cloud model (Roche Allred & Bretz, 2019). While many studies have highlighted the challenges student encounter with atomic structure models, few have investigated their conceptual knowledge in combination with their epistemic knowledge.

Our study aims to expand on this by exploring students' epistemic atomic modelling knowledge, self-generating ability of atomic model, and operational knowledge of atomic models. In this way, we are eliciting students' general conceptions of atomic models, their highest level of sophistication of epistemic modeling knowledge, how often they use the same or different criteria to explain models, and to identify patterns and any relationship between epistemic knowledge (thinking about models) and operational knowledge, if there exist any.

Semi-structured interviews were carried out to allow for an in-depth understanding of students' conceptions of atomic models and their epistemic modeling knowledge. Interviews were audioand video-recorded, and the transcripts were generated using Otter.ai. Transcripts were analyzed to identify patterns and emerging themes. The thematic analysis showed that students have strong preference using concrete ideas to interpret atoms and the subatomic particles as seen in other studies with many students exhibiting naïve views of atomic structure and a reliance on classical models. Students possessed epistemic modeling knowledge with varied sophistication. Results include specific ways students approach and make sense atomic structure as well as general conceptions of scientific models. The relationship between their operational and epistemic knowledge will be discussed and related implications for introducing atomic structure models in the classroom.

References

Harrison, A.G. and Treagust, D.F. (1996), Secondary students' mental models of atoms and molecules: Implications for teaching chemistry. *Science Education*, 80: 509 534. https://doi.org/10.1002/(SICI)1098-237X(199609)80:5<509::AID-SCE2>3.0.CO;2- F

Lazenby, K., Stricker, A., Brandriet, A., Rupp, C. A., Mauger-Sonnek, K., & Becker, N. M. (2020). Mapping undergraduate chemistry students' epistemic ideas about models and modeling. *Journal of Research in Science Teaching*, *57*(5), 794–824. https://doi.org/10.1002/tea.21614

Meng-Fei Cheng & Jang-Long Lin (2015). Investigating the Relationship between Students' Views of Scientific Models and Their Development of Models, *International Journal of Science Education*, 37:15, 2453-2475, DOI: 10.1080/09500693.2015.1082671

Papageorgiou, G., Markos, A., & Zarkadis, N. (2016). Students' representations of the atomic structure-the effect of some individual differences in particular task contexts. *Chemistry Education Research and Practice*, *17*(1), 209–219. https://doi.org/10.1039/c5rp00201j

Roche Allred, Z. D., & Bretz, S. L. (2019). University chemistry students' interpretations of multiple representations of the helium atom. *Chemistry Education Research and Practice*, *20*(2), 358–368. https://doi.org/10.1039/C8RP00296G

Zarkadis, N., Papageorgiou, G., & Stamovlasis, D. (2017). Studying the consistency between and within the student mental models for atomic structure. *Chemistry Education Research and Practice*, *18*(4), 893–902. https://doi.org/10.1039/c7rp00135e

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Examining the Impact of Design-Based Research Methods on Project Implementation Introduction

Skylar Hubbarth, Anna G. Hunter, Shannon Conner & D. Matthew Boyer (Clemson University)

Introduction The Student Pathways in Engineering and Computing for Transfers (SPECTRA) program is a Scholarship program for the Clemson University College of Computing, Engineering, and Applied Sciences (CECAS) supported by NSF S-STEM Award 1834081. With respect to the educational research aspects of the project, since its start in Fall 2019, SPECTRA has shown how data analysis can be informed by implementation and vice versa. Evidence from iterations of formative reflection in the design-based research study have been used to revise project implementation and add to methods for data collection and analysis. Data-driven issues that emerge from these iterations of analysis within the context of implementation are timely and meaningful for internal metrics of project evaluation and providing data that address existing and emergent research questions. The primary goal of SPECTRA research has been to analyze impacts on the SPECTRA Scholars, i.e., the undergraduate transfer students in STEM majors, and constantly work to improve the program for their benefit. In this study, we investigate how the implementation of surveys and interviews has impacted the redesign of methods, questions, and program operations throughout the operational semesters of the SPECTRA program.

Background: Design-Based Research In the context of the SPECTRA program, our use of design-based research (DBR) has emerged as a cornerstone methodology facilitating iterative advancements grounded in empirical analysis (Robles et al., 2023). At its core, DBR serves as a pragmatic approach to intervention research, manifestly evident in this study where iterative evaluations are employed to continually fine-tune the program to meet the evolving needs of the students. Our implementation is data-informed, with structured surveys and interviews used to glean insights into students' social and academic experiences within the SPECTRA program. As the SPECTRA initiative has continued, DBR plays an instrumental role in facilitating a reflective process wherein data derived from new and returning Scholars are methodically analyzed to ascertain the program's impacts on various facets of students' academic journeys, particularly focusing on their confidence levels in mathematics and their preparedness in their chosen fields of study.

Significance We are using this reflection on four years of project data collection and analysis to identify how the use of design-based research methods have impacted project implementation in an effort to understand the affordances and constraints of DBR methods.

Research Question What is the impact of evidence from iterations of human subjects data collection and analysis on the design and implementation of the SPECTRA program?

Methods: Data Collection New and returning SPECTRA Scholars have been asked to partake in a survey at the start of each semester since the Spring 2020 semester, along with the opportunity to interview further into the semester. In addition to being used as data to address research questions, responses from surveys have also been used to inform program evaluation. Survey results illuminate the need to include any participant-specific questions during interviews to clarify or amend survey For this specific study examining the impact of methodological decisions, we have aggregated all of the survey and interview data across the first four years of the SPECTRA program for analysis.

Methods: Data Analysis We use descriptive statistics to identify areas of change across survey data and thematic analysis of interview data to find patterns in the evidence. After identifying the incidences of substantive changes in the data, we have looked at the evidence across the project timeline to show when and how data-driven revisions impacted student experiences. For example, we were able to see improvements when comparing data across semesters; returning students felt more confident that they would do well in their chosen major, felt more confident about their mathematics knowledge, skills, and abilities in light of their chosen major, and felt more prepared by their previous math courses for their current math courses when compared to the new students. Our results indicated that while their academics improved, students still wanted more events, activities, and social interaction. With results like these, we have been able to modify data methods and project implementation to allow for further improvements to Scholars' experiences in the SPECTRA program.

Conclusion An integral component of DBR is its cyclic nature, involving continuous cycles of implementation, reflection, and potential revisions based on accumulated data, thereby informing modifications to both data collection strategies and program implementation. This has been illustrated in the SPECTRA program's ongoing effort to enhance the Scholars' experiences. The iterative feedback loops intrinsic to DBR allow for the nuanced adaptation of the program's operational elements, fostering a dynamic ecosystem wherein Scholars' feedback actively contributed to refining the program structure, nurturing both academic and social improvements. Furthermore, DBR underscores a symbiotic relationship between theory and practice, showcasing its utility in guiding real-world project implementation. In the SPECTRA program, this meant acknowledging and responding to the Scholars' growing demand for increased social interactions, events, and activities, an aspect that was brought to the fore through the iterative evaluations. Thus, the integration of DBR in the SPECTRA program not only facilitates a systematic approach to intervention research but also engenders a responsive, adaptive, and more effective program that caters holistically to the needs and aspirations of the Scholars.

Reference

Robles H, Jimeno M, Villalba K, Mardini I, Viloria-Nuñez C, Florian W. (2023.) Design of a micro-learning framework and mobile application using design-based research. P*eerJ Computer Science 9*:e1223 □ttps://doi.org/10.7717/peerj-cs.1223

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Exploring the Impact of a Science Communication Lesson on Undergraduate Biology Students' Ability to Communicate about Culturally Controversial Science Topics

Katie Coscia, Casey Epting, Alexa Summersill, M. Elizabeth Barnes (Middle Tennessee State University)

Introduction Open and respectful dialogue over potentially divisive science topics like vaccines, climate change, and evolution seems to be increasingly difficult. Many science topics are relevant to public health and welfare, yet the spread of misinformation and the politicalization of these topics suggests that scientists are often unsuccessful in their attempts to communicate research findings to the wider public (Lewandowsky et al., 2021). One component of the communication problem is a lack of acknowledgment of the interplay between peoples' identities, backgrounds, and their relationships with science (Hart and Nisbet, 2012). Fortunately, undergraduate science students not only represent a wide diversity of identities and potential career paths, but some of them will also serve as the next generation of scientists. Undergraduate students can be boundary spanners within highly science-hesitant communities by conveying scientific information in a way that is contextually relevant and builds upon pre-existing relationships (Shah, Simeon, Fisher, & Eddy; 2022)

Recent evidence suggests that undergraduate students are already engaging in science communication about controversial science topics, but they are doing so with varying degrees of confidence and efficacy (Bowen et al., in press; Couch et al., 2022). Although these students are already actively communicating about science, few undergraduate students are receiving science communication training as a component of their science curricula (Brownell et al., 2012; Edmonston et al., 2010). While many studies focus on science communication instruction in upper-level biology courses (Brownell et al., 2013; Goldina and Weeks, 2014; Iriart et al., 2022), there is little research on the potential impact of science communication training at the introductory level, particularly when it comes to preparing students to discuss controversial science topics such as climate change and vaccines. Our present study is among the first to address science communication specifically over controversial topics, students' interpersonal communications, and if science communication training on one controversial topic provides skills that can be transferred to another controversial topic. We implemented science communication training and explored whether it increased undergraduate students' use of effective communication strategies like focusing on common values, showing respect and empathy, and listening (Bray et al., 2012). We also explored whether the instruction decreased their use of ineffective strategies like negative communication, avoidance of communication, and an overreliance on scientific facts in their communication (Ahteensuu, 2012).

Research Questions

1. To what extent does a science communication module increase/decrease students' use of effective science communication principles when they are asked how they would communicate about culturally controversial science topics?
2. Does the knowledge students gain about communication focused on one controversial topic (climate change) transfer to their communication strategies when they are asked to communicate about another controversial topic (vaccines)?

3. How would a science communication training module in an undergraduate biology course impact students' experiences (i.e., confidence, preparedness, value for the communication) in communicating about controversial science topics?

We address these questions first by including science communication training as part of an undergraduate introductory biology course at a mid-sized public university in the southeastern United States. Before the training, students are prompted to share how they would respond to someone expressing the belief that climate change is not caused by humans. After instruction on effective science communication, they were asked to reflect on their prior responses and use what they learned to identify which effective and ineffective strategies they had used. Students were then asked to revise their responses. Finally, to see if student knowledge transferred to a different culturally controversial science topic, students were asked to write how they would respond to someone who is questioning whether to receive a vaccine. We are now in the process of interviewing students about their experiences conversing about controversial science topics since receiving science communication training and how that training influenced their communication.

Data Analysis and Results Student responses were analyzed to identify themes of effective and ineffective science communication strategies before and after the science communication module (n = 19). These preliminary data show that science communication training positively impacted students' use of effective communication strategies, at least within the context of the assignment. However, interviews still need to be conducted to assess how science communication training impacted students' communication outside of the classroom and we will begin interviewing these students from Spring 2023 in October.

Additionally, science communication instruction and data collection will be repeated in two introductory biology courses this semester, providing an anticipated sample size of n = 150 students. To evaluate students' open-ended worksheet responses, we will conduct deductive thematic analyses to identify effective and ineffective communication strategies. We will analyze interview responses with both deductive and inductive thematic analysis (Krippendorf 2019). Deductive analysis will be aimed at identifying students' usage of both effective and ineffective strategies in their science communication. Inductive analysis will ascertain how the training module affected (or did not affect) students' confidence in communicating about controversial topics and their value for science communication.

Conclusion Our current data suggests that science communication instruction can improve how students would communicate about controversial science topics and that these communication skills can be transferred from one topic to another. However, because of the small sample size, we need to collect more data, so we plan to repeat the science communication instruction during Fall 2023 with an estimated 150 students. To investigate how the instruction may impact students' actual communication, we will be interviewing them about their experiences communicating science topics with family and friends over the summer and winter breaks. With this study, we hope to establish whether a brief training on science communication can have a significant impact on students' ability to have open, respectful, and impactful dialogue, both within and without their communities, over multiple controversial science topics.

References

Ahteensuu, M. (2012). Assumptions of the Deficit Model Type of Thinking: Ignorance, Attitudes, and Science Communication in the Debate on Genetic Engineering in Agriculture. J Agric Environ Ethics. 25, 295–313. https://doi.org/10.1007/s10806-011- 9311-9

Bowen, C., Summersill, A. R., Aadnes, M., Google, A., & Barnes, M. E. (n.d.). Black Undergraduate Biology Students' Communication about COVID19 Vaccines within Their Communities and Their Learning Experiences in Biology Classes about How to grCommunicate Effectively. CBE—Life Sciences Education.

Bray, B. (1), France, B. (2), & Gilbert, J.K. (3). (2012). Identifying the Essential Elements of Effective Science Communication: What do the experts say? International Journal of Science Education, Part B: Communication and Public Engagement, 2(1), 23-41. https://doi.org/10.1080/21548455.2011.611627

Brownell SE, Price JV, Steinman L. (2013). A writing-intensive course improves biology undergraduates' perception and confidence of their abilities to read scientific literature and communicate science. Adv Physiol Educ. 37:70–79.

Couch, B., Wybren, E., de Araujo Bryan, M., Niravong, T., Jin, Y., Bowen, C., & Barnes, M. E. (2022). Exploring Undergraduate Biology Students' Science Communication About COVID-19. Frontiers in Education, 7. https://www.frontiersin.org/articles/10.3389/feduc.2022.859945

Edmondston, J., Dawson, V., & Schibeci, R. (2010). ARE STUDENTS PREPARED TO COMMUNICATE? A CASE STUDY OF AN AUSTRALIAN DEGREE COURSE IN BIOTECHNOLOGY. International Journal of Science and Mathematics Education, 8(6), 1091–1108. https://doi.org/10.1007/s10763-010-9234-3

Goldina, A., & Weeks, O. I. (2014). Science Café Course: An Innovative Means of Improving Communication Skills of Undergraduate Biology Majors. Journal of Microbiology & Biology Education, 15(1), 13–17. □ttps://doi.org/10.1128/jmbe.v15i1.678

Hart, P. S., & Nisbet, E. C. (2012). Boomerang Effects in Science Communication: How Motivated Reasoning and Identity Cues Amplify Opinion Polarization About Climate Mitigation Policies. Communication Research, 39(6), 701–723. https://doi.org/10.1177/0093650211416646

Iriart, V., Forrester, N. J., Ashman, T.-L., & Kuebbing, S. E. (2022). The Plant Science Blogging Project: A curriculum to develop student science communication skills. Plants, People, Planet, 4(5), 485–498. https://doi.org/10.1002/ppp3.10287

Krippendorff, K. (2019). Content analysis: An introduction to its methodology (Fourth edition). SAGE.

Lewandowsky, S., Cook, J., Schmid, P., Holford, D., & Finn, A. (2021). The COVID-19 Vaccine Communication Handbook. https://hackmd.io/@scibehC19vax/home

Shah, H., Simeon, J., Fisher, K. Q. & Eddy, S. L. (2022). Talking Science: Undergraduates' Everyday Conversations as Acts of Boundary Spanning That Connect Science to Local Communities. CBE—Life Sciences Education, 21(1). https://doi.org/10.1187/cbe.21-06- 0151

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Initial Impacts of a Community-Engaged Learning Focus on Pre-Service Teachers in an Early STEM Collaboration Background Literature

Amie Perry & Alissa Lange (East Tennessee State University)

Background Literature The integration of community engagement learning into university programs has gained increasing attention in recent years. Incorporating community-engaged learning (Jacoby, 2015) into pre-service teacher preparation programs can allow students to experience a practical application of pedagogical knowledge, foster cultural competence, enhance pedagogical strategies, and build professional networks (Thomas et al., 2020, Zygmunt et al., 2018). The Appalachian region struggles to retain highly qualified teachers and prepare students for STEMrelated careers (Wright et al., 2016). Incorporating community-engaged learning with pre-service teachers in a science and STEM course could enhance teacher retention in the region because, 1) intentional interactions with professionals have been shown to increase commitment to the profession (Garza et al., 2016), 2) authentic experiences that link theory to practice may lead to transformative learning (Hoggan, 2016).

In order to address this, we incorporated a community-engaged learning focus into our current STEM collaboration model (Lange et al., 2022), which is a collaborative approach to preservice teacher preparation in early and elementary science and STEM courses in the Southeast United States. The goal of the model is to improve science and integrated STEM teacher preparation, and the model has been shown to impact pre-teacher self-efficacy in prior years positively (Lange et al., 2022). Our poster will describe the initial effects of community-engaged learning opportunities embedded in the model. These research questions guide the study:

1) How did the community-engaged learning focus affect pre-service teacher's knowledge of community resources?

2) What are pre-service teachers' views on the community-engaged learning aspect of the STEM Collaboration?

Methodology STEM Collaboration Model The STEM collaboration model is an innovative collaboration between early childhood and elementary education departments that is designed to improve pre-service teacher's early STEM preparation. The model draws on the philosophies of both programs and integrates the ideas (Robertson et al., 2020). This semester's implementation of the early science and integrated STEM course involved pre-service teachers' professional presentations at a regional STEM event hosted by a children's science museum; early childhood and elementary pre-service teachers meeting across the semester; guest lectures by teachers and faculty; applied microteaching with students, and opportunities to co-write and co-present. Design, Participants, & Instrument In order to answer the research questions, students enrolled in the STEM courses responded to open-ended questions about the community-engaged learning aspect of the collaboration, such as, "What places in our community could support science learning?"

The responses to the survey and written reflections about the professional presentation experience from the students were collected, and the data were analyzed by the instructors of one section of the course. The data were coded inductively, with grounded theory as the guided approach (Ravitch & Carl, 2021). Researchers interpreted the data once it was coded, and three themes emerged.

Findings The themes that emerged from the data include 1.) increased awareness of community resources, 2.) disequilibrium, and 3.) pedagogical shifts. Pre-service teachers demonstrated increased awareness of community resources that could be utilized in their future teaching. The second theme, disequilibrium, was expressed in written reflections as well as through verbal discussions with instructors before the meeting took place. After the meeting, students revealed that conversation with the educators was helpful to them, and several students shared that this helped them feel more comfortable talking with in-service teachers. The third theme, pedagogical shifts, emerged from the reflections on the course experience at the end of the semester. Pre-service teachers made direct connections to the community-learning experience, altering their plans for teaching in the future. One student wrote, "I felt inspired by my experiences to design unique learning opportunities and create engaging, applicable to the real world, science lessons." This idea of feeling inspired and using community resources in their future teaching was expressed by many students in the courses, indicating that this experience has had a direct impact on their teaching pedagogy.

Implications The initial findings of this study indicate that community-engaged learning experiences should be incorporated into more pre-service teacher preparation programs, specifically when thinking about science and integrated STEM teaching. Students in the course were better able to identify resources from the community that they could use in their teaching career and expressed their plans to utilize those resources. These experiences also have caused pedagogical shifts, further emphasizing the need for pre-service teachers to engage in authentic experiences that will transform their future teaching and, therefore, future students who are learning science and STEM concepts. In addition to the community-engaged learning experiences, pre-service teachers should also be offered more professionalization opportunities. This professionalization opportunity was uncomfortable for many of the pre-service teachers, but they still expressed how meaningful this experience was to them.

References

Garza, R., Werner, P., Wendler, L. F. (2016). Transitioning from student to professional: Preservice teachers' perceptions. *New Waves Educational Research & Development*, 19(2).

Hoggan, C. D. (2016). Transformative learning as a metatheory: Definition, criteria, and typology. Adult Education Quarterly, 66(1).

Jacoby, B. (2015). Service learning essentials: Questions, answers, and lessons learned. San Francisco, CA: Jossey-Bass.

Lange, A. A., Robertson, L., Tian, Q., Nivens, R., & Price, J. (2022). The effects of an early childhood-elementary teacher preparation program in STEM on pre-service teachers. *Journal of Mathematics, Science and Technology Education*, 18(2).

Ravitch, S. M., & Carl, N. M. (2021). Qualitative research: Bridging the conceptual, theoretical, and methodological (2nd ed.). SAGE Publications.

Robertson, L., Nivens, R., & Lange, A. A. (2020). Tackling integrated STEM in elementary education: A collaborative approach. *International Association of Laboratory Schools, X(1), 1-13.* https://www. researchgate.net/publication/340898763_Tackling _Integrated_STEM_in_Elementary_Education_A_ Collaborative_Approach

Thomas, C. L., Tancock, S. M., Zygmunt, E. M., & Sutter, N. (2020) Effects of community-engaged teacher preparation program on the culturally relevant teaching self-efficacy of preservice teachers. *The Journal of Negro Education,* 89(2).

Wright, D., Cunningham, B., & Stangle, J. (2016). *The Appalachian region: A report identifying and addressing the region's educational needs*. Insight Policy Research.

Zygmunt, E., Cipollone, K., Tancock, S., Clausen, J., Clark, P., & Mucherah, W. (2018). Loving out loud: Community mentors, teacher candidates, and transformational learning through a pedagogy of care and connection. *Journal of Teacher Education*, 69(2).

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Interdisciplinary Assessment of Student Thinking About Variability

Fonya Scott (Middle Tennessee State University), Rebecca Klukowski (University of Louisville), Kaytlin Campbell (Middle Tennessee State University) & Oscar Meza-Abarca (Middle Tennessee State University)

Introduction Making decisions with data is an essential skill that includes thinking about statistical practices and their context (Franklin et al., 2007). The fundamental ideas about data analysis are often expected to be mastered in mathematics classes but are essential for building an understanding of the natural world in science classes. The expectation of using data to support scientific claims is an essential part of research methods at each level of science instruction. Students are asked to create data sets and make claims with data or analyze data collected by others in science classes. In fact, NGSS standards include analyzing and working with data at every grade level. Usiskin and Hall suggested that for most K-12 students, making decisions based on statistics is discussed more often in science than mathematics (2015). Statistics instruction, however, has been primarily the responsibility of mathematics teachers.

This pattern of instruction often creates a challenge for students trying to make connections across disciplines and is likely to create disjointed learning experiences. However, research has shown that interdisciplinary ideas can be supported in coherent ways across disciplines. Although there is some evidence of supporting learning across disciplines (Lehrer & Schauble, 2004; Makar & Confrey, 2003), there are no assessment tools to generate evidence about student thinking across disciplines and in cross-disciplinary constructs (Gao et al., 2020).

When correctly implemented, classroom assessments help teachers understand what students know and what needs to be done to support students moving toward mastery of objectives and standards (Pelligrino, 2013). For interdisciplinary content, however, assessments present challenges (Drake & Reid, 2018). To address the need for an interdisciplinary assessment, we developed instruments intended to serve as formative assessments for mathematics or science teachers to collect evidence to support inferences about students' connections between quantitative and qualitative descriptions of variability.

Research Questions This presentation will address two of our research questions driving the development of the assessment tools:

(RQ1) How can construct modeling be used for interdisciplinary assessment of student thinking about statistical variation and ecological variability?

(RQ2) What evidence supports the use of interdisciplinary assessment items as valid measures of the variability construct?

Methodology This study is part of a more extensive research project, the Integrated Data Project (IDP), that explores opportunities for collaboration of middle school mathematics and science teachers to teach statistical-based model inference. Using the four building blocks of Wilson's BEAR framework for constructing measures, I developed five assessment instruments to assess patterns of student thinking about variability. Open-ended (e.g., written response and drawing) and multiple-choice items were developed. Each assessment instrument includes a scenario describing the ecological context, related illustrations supporting the scenario, data displays, open-ended prompts, and multiple-choice questions. Middle school mathematics and science teachers administered the assessments at Heavenbow Middle School in the southeastern United States. Mathematics teachers at Heavenbow have been using curriculum materials for developing students' understanding of data developed by Dr. Richard Lehrer for over five years. The science teachers had been working for three years with our team to coordinate their instruction with the data units the students experience in the math classes.

We trained a team of three scorers on our construct map that outlines the development of students' understanding of variability. The team of scorers, including the author, scored the completed items. Consensus scores were determined once all scorers formed a mutual agreement. Our poster will show how the measuring plants instrument prompted student responses that reflect various levels of the construct map to reveal the development of student thinking as they explore factors that may result in variation as they consider a group of students observing the growth of plants.

Data Analysis and Results Early data analysis shows that most students recognized variability in data, which is an early step essential to statistical practice (Pfannkuch, 2005). This pattern was expected as the students completed a similar activity in their mathematics and science classes. A review of the total scored responses to items on the growing plants assessment (n=1168) suggests that most students (64.3%, n=751) in our sample were able to recognize and describe variation. However, students vary in their ability to make meaning of the variability as part of a data set or in the scientific context (Table 1). These students scored at level 2 (difference measured) (23%, n=269), level 3 (difference structured) (20.4%, n= 228), and level 4 (difference explained) (21.8%, n= 254). The patterns observed in early item scoring suggest it may be much more difficult for students to use data and the phenomenon to construct an explanation (level 4).

Table 1

Sample responses at construct levels 2, 3, and 4

Construct level	**Sample response**
Level 2 Difference Measured: Develop or appropriate a measure and apply it to a collection.	"I think the plant will be 11 cm tall in 9 days because the data shows it."
Level 3 Difference Structured: Structure a collection of measures as a distribution and measure distributional features with statistics.	"I think the plant will be 18 cm tall in 9 days because there is a bunch of them *(data points)* together in a group."
Level 4 Difference Explained: Construct explanations that account for sources of variability.	"I think the plant will be 24 cm tall in 9 days because the plant is growing faster as it gets older. The mean each day is getting higher more"

Because the instrument is designed to reveal understanding across the EV construct, it is useful for science teachers who desire students to reason about a phenomenon based on data and for mathematics teachers looking for evidence of conceptual understanding of variability.

Implications According to the Guidelines for Assessment and Instruction in Statistics Education (GAISE) report, understanding variation is at the core of developing the skills needed for data interpretation (Franklin et al., 2007). Because explaining variation is central to statistical and scientific thinking, understanding how student thinking develops benefits educators in both mathematics and science classrooms. In an interdisciplinary consideration of variability, there must be purposeful thinking of how the context influences describing variability. Construct modeling allows the development of ideas from different disciplines to be revealed using the same assessment. With the EV construct, this assessment provides teachers and students a tool to map progress toward the essential skill of analyzing and interpreting data in a meaningful way.

Bibliography

Drake, S. M., & Reid, J. L. (2018). Integrated curriculum as an effective way to teach 21st century capabilities. *Asia Pacific Journal of Educational Research*, *1*(1), 31-50.

Franklin, C., Kader, G., Mewborn, D., Moreno, J., Peck, R., Perry, M., & Scheaffer, R. (2007). Guidelines for assessment and instruction in statistics education (GAISE) report. Gao, X., Li, P., Shen, J., & Sun, H. (2020). Reviewing assessment of student learning in interdisciplinary STEM education. *International Journal of STEM Education, 7*(1), 1–14. Lehrer, R., & Schauble, L. (2004). Modeling natural variation through distribution. *American*

Educational Research Journal, *41*(3), 635-679. Makar, K., & Confrey, J. (2003). Chunks, Clumps, and Spread Out: Secondary Preservice Teachers' Informal Notions of Variation and Distribution. *Reasoning about Variability: A Collection of Current Research Studies*.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices,Crosscutting Concepts, and Core Ideas*. National Academies Press. Pellegrino, J. W. (2013). Proficiency in science: Assessment challenges and opportunities.*Science*, 340(6130), 320-323.

Pfannkuch, M. (2005). Thinking tools and variation. *Statistics Education Research Journal*, *4*(1), 83-91.

Wilson, M. (2005). *Constructing Measures: An Item Response Modeling Approach: An ItemResponse Modeling Approach*. Routledge

Usiskin & Hall, K. (2015). The relationships between statistics and other subjects in the K-12curriculum. Chance, 28(3), 4-18.

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Investigating Factors Influencing Science Student Retention Introduction Retention in and across STEM degrees has been a significant problem across institutions

Hayley Benson & Morgan Balabanoff (University of Louisville)

Introduction By the time students have reached their third year, University of Louisville has lost over 50% of the students who entered as first year students. The issue of retention is not unique to UofL with many studies identifying stark differences in the number of intended STEM majors and the actual number of graduates nation-wide (Seymour & Hunter 2019). In an effort to mitigate this issue, UofL has implemented new programs to increase early student success STEM. Specifically, the James Graham Brown Foundation has funded a program which aims to increase early student success in required STEM+H (Science, Technology, Engineering, Math, and Health Sciences) courses in math, biology, and chemistry that traditionally have high DFW rates which has implications for potential underrepresentation in the workforce. While there have been efforts to better support students, there remains a need to investigate whether these high DFW rates are issues related to student supports (i.e., needing extra resources) or if there are social and community issues (i.e., belonging, mindset, science capital, etc.). Researchers investigated how positive and negative experiences in a course can impact whether a student chooses to continue pursuing their STEM degree (Seymour & Hunter 2019). Early classroom performance was also seen to impact a students' science identity (Cimpian et al. 2020).

Study Objective The main objective of this study is to investigate variables such as sense of belonging, student's mindset, and science identity and their relationship with retention in STEM degrees. While many studies have identified gaps among student groups across these variables, few studies have generated solutions to address these gaps. Further, the proposed solutions are often from the viewpoint of researchers and upper administration who indeed persisted through the current state of higher education potentially limiting the applicability to students in jeopardy of leaving. Therefore, this study involves eliciting ideas directly from current students related to their belonging, mindset, and identity and how to address issues of retention from their perspective. To capture uncensured student perspectives about potentially sensitive topics, undergraduate STEM students collected peer-led focus groups (Djohari & Higham 2020) where they serve as both participant and moderator.

Data Analysis and Results Students enrolled in science courses at the University of Louisville are the target population the study, specifically recruited in introductory biology and chemistry courses. These students were organized into groups to participate in interviews led by undergraduate researchers. Because the undergraduate researchers are STEM students enrolled at the university, they both shared their perspectives and prompted participants to share theirs. The unstructured format of the focus group relies on the peer interviewer to direct the discussion. The broad themes guiding the discussion included: current attitudes towards classes and degrees, science capital, belonging in science, and identifying areas they need more support. The goal was for the themes and topics to come up naturally as students chose to discuss their thoughts, however, the peer interviewer periodically engaged and steered the conversation. Interviews lasted between 60 - 120 minutes and were transcribed from audio and video recordings. Using a phenomenological approach, interview data was analyzed to identify trends from the focus group interviews. Patterns across the broad themes will be presented with a particular focus on external and internal motivation factors and accompanied by potential solutions generated from students' perspectives.

References

Djohari, N. & Higham, R. (2020). Peer-led focus groups as "dialogic spaces" for exploring young people's evolving values. Cambridge Journal of Education, 50(5), 657–672. https://doi.org/10.1080/0305764x.2020.1754763

Joseph R. Cimpian et al., Understanding persistent gender gaps in STEM. *Science* **368**, 1317-1319 (2020). DOI:10.1126/science.aba7377

Seymour, E., & Hunter, A.-B. (2019). *Talking about leaving revisited.* Springer.

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Investigating Pre-health Students' Science Identity and the Factors That Influence Them to Change Programs or Tracks

Taylor Humphreys & Morgan Balabanoff (University of Louisville)

Introduction Retention rates for undergraduate students in pre-health programs or tracks have had a continual decline as students progress through their bachelor's degrees. In 2020, 16.5% of students who intended to follow a pre-med track graduated with the course requirements to apply to medical school (Zhang, Kuncel, & Sackett, 2020). While numerous articles publish statistics regarding students on a pre-med track with intentions to apply to medical school, information is not available for pre-health students applying to other health professional schools (dental school, pharmacy school, physician assistant school, physical therapy school, etc.). It is important to know what measures can be taken or resources offered to improve the retention rates across these programs or tracks.

Research Questions To dive deeper into science identity, retention, and resources specifically for pre-health students, data collection and analysis of this project was guided by the following questions:

RQ 1. How do pre-health students define and describe their science identity?

RQ 2. What factors cause pre-health students to change their program or track?

RQ 3. What resources do students perceive as beneficial to aid in their academic journeys?

Literature Background With a large amount of pre-health students' perquisite courses being within the STEM field, it was found that pre-med and other pre-health students were more likely to have a higher STEM identity than their peers with performance-competence, recognition, and interest playing a role as contributing factors (Dou, Cian, & Espinosa-Suarez, 2021). Many pre-health students begin their first semester in multiple introductory courses in several different STEM disciplines. Their high immersion into the STEM field made them feel a stronger sense of belonging than others in their classes without this experience.

Many factors play a role in attrition in pre-health programs or tracks. Attrition has found to have its highest rates early on in undergraduates' careers as they begin to understand the commitment and requirements their programs or tracks hold. Demographics, academic preparedness, and coursework have also been identified as factors linked to attrition in pre-health students (Zhang, Kuncel, & Sackett, 2020). One or more of these factors often cause students to switch their programs or tracks, but there are circumstances where students can be motivated to pursue nonmedical careers in STEM from undergraduate experiences. These experiences could be in the form of research, teaching, or something different and unique to that student (Dou, Cian, & Espinosa-Suarez, 2021). These factors are difficult to differentiate from each other due to their statistics often being reported together.

Methodology Peer-led focus groups were used to elicit uncensored responses from students. Focus groups allowed for a small number of participants with similar interests or qualities (the basis for group assignment) to discuss a series of open-ended questions (Glitz, 1997). The group environment allowed for students to express their opinions as well as build off the opinions and ideas other participants present. For more exploratory talk, the focus groups were peer-led with student moderators and contributors rather than led by a figure of authority (i.e., a professor) (Djohari & Higham, 2020). Students used familiar vocabulary and lingo when conversing with their peers that may have shifted to use more professional terms in the presence of an authoritative figure. By being peer-led, the students felt more comfortable and open to discussing sensitive or "taboo" topics than they would if a teacher or parent had been in the room. Audio and video recording was used to capture the interviews and they were uploaded to an online transcription service (Otter.ai) and MAXQDA was used to code for common themes.

To analyze the variety of data that was collected, two frameworks were utilized: Social Learning Theory and Science Identity Model. Social Learning Theory emphasizes the influence of observational learning. Individuals obtain behavior, knowledge, and expectations through observing, imitating, and modeling others (McLeod, 2023). This lens was used to look at which experiences shaped students' perspectives of their programs or tracks and which factors led some participants to change programs or tracks. Science Identity Model uses the three interrelated dimensions of competence, performance, and recognition to capture science identity. Competence refers to knowledge and understanding of science content, performance refers to social performances of scientific practices, and recognition refers to self-recognition and recognition by others as being a "science person" (Carlone & Johnson, 2020). This lens was used to look at how students define their own science identity in addition to their sense of belonging within their programs or tracks.

Results Once the peer-led focus groups were conducted, the interviews were transcribed and qualitatively analyzed using a phenomenological approach. This approach focuses on the researchers' immersion into the participants' experiences to derive their details and meanings without bias or any preconceived notions (Rodriguez & Smith, 2018). Through doing this, factors related to decreasing retention rates among pre-health students were identified along with resources students would like to see increased or introduced to aid in their academic journeys.

References

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. Journal of Research in Science Teaching, 44(8), 1187–1218. https://doi.org/10.1002/tea.20237

Djohari, N. & Higham, R. (2020). Peer-led focus groups as "dialogic spaces" for exploring young people's evolving values. Cambridge Journal of Education, 50(5), 657–672. https://doi.org/10.1080/0305764x.2020.1754763

Dou, R., Cian, H., & Espinosa-Suarez, V. (2021). Undergraduate STEM Majors on and off the Pre-Med/Health Track: A STEM Identity Perspective. CBE—Life Sciences Education, 20(2), ar24. https://doi.org/10.1187/cbe.20-12-0281

Glitz B. (1997). The focus group technique in library research: an introduction. Bulletin of the Medical Library Association, 85(4), 385–390.

McLeod, S. (2023, February 16). Albert Bandura's Social Learning Theory. Simply Psychology. https://www.simplypsychology.org/bandura.html

Rodriguez, A., & Smith, J. (2018). Phenomenology as a healthcare research method. Evidence-Based Nursing. https://ebn.bmj.com/content/21/4/96

Zhang, C., Kuncel, N. R., & Sackett, P. R. (2020). The process of attrition in pre-medical studies: A large-scale analysis across 102 schools. PLOS ONE, 15(12), e0243546. https://doi.org/10.1371/journal.pone.0243546

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Investigating The Utility of and Barriers to Educational Resources for Students in STEM

Claire Ward & Morgan Balabanoff (University of Louisville)

Abstract According to data collected from institutions around the US, more than half of first-year science majors drop out before receiving their degrees, and more than half of STEM bachelor's degree holders switch to non-STEM degrees before completing their degrees. 1,2,3,4 Currently, there is a diverse body of literature showing that retention in STEM is related to a strong sense of belonging, a growth mindset, interest and engagement in the sciences, and academic supports.5,6,7,8 This trend of high movement out of STEM majors is also seen at the University of Louisville, where retention of first year full-time students in the College of Arts & Sciences at University of Louisville is on average 83.6% from their first year fall semester to spring semester, 62.8% from first to second year and 47.4% from first to third year. The pandemic caused a decline in retention. Between Spring 2021 and Spring 2022, retention was particularly low, especially for Sophomores and Juniors. By their third year, over 50% of the students who entered as first year STEM students are no longer in their intended major. This trend holds for students majoring in the sciences, biology, chemistry, geosciences, physics, and math.

The overall goal of this project was to assess factors relating to retention and the intention to persist among science majors in their first two years of college as well as inform improvements in programming in science departments. The specific goals of this study are to:

1. Develop a quantitative survey for students to identify utilized university-level and department-level resources, barriers to these resources, and potential resources gaps.

2. Characterize students' use of campus resources and identify areas of improvement through collection of unstructured focus-group interviews led by peer-moderators (fellow undergraduate science students).

An initial survey collection was carried out in Fall 2022 to address the first goal. In this survey, science majors and non-majors were asked about their sense of belonging, mindset, perceptions of the value of and interest in science, and career intentions. Students were also asked to rank their attitudes toward these factors and to list the resources they use as students and what they would like to see more of in campus. 6,8,15 Using sequential exploratory analysis, the open-ended responses were coded and used to generate close-ended responses. These codes informed discussion points for moderators in the subsequent peer-led focus group interviews.

A series of peer-led focus group interviews were held to address the second goal. Each interview was conducted in small groups of four to five students and was moderated by fellow undergraduate science students on the research team. Using peer-moderators allowed the creation of open dialogic spaces that avoid self-censure that can emerge in the presence of a PI moderator, resulting in unfiltered, genuine responses. This is crucial when participants lack access to similar spaces for collaborative inquiry into their shared experiences and are structurally disadvantaged. 16 Participants discussed what resources they used, how they used them, what barriers they faced in accessing resources, and gaps in these resources that

diminished their use. The findings from both focus group interviews and quantitative survey data were examined through the lens of how students use the resources provided and the physical barriers to those resources. This analysis provides recommendations for university improvements as well as conclusions about which systems work well within the university.

References

[10]Astin, A.W., and Astin, H.S. (1992). *Undergraduate Science Education: The Impact of Different College Environments on the Educational Pipeline in the Sciences*. Los Angeles: The Higher Education Research Institute, University of California, Los Angeles.

[5]Burtner, J. (2005). The Use of Discriminant Analysis to Investigate the Influence of Non-Cognitive Factors on Engineering School Persistence. *Journal of Engineering Education*, *94*(3): 335−338.

[1]Chen, X. (2009). *Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education* (NCES 2009-161). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

[16]Djohari & Higham (2020) Peer-led focus groups as 'dialogic spaces' for exploring young people's evolving values, Cambridge Journal of Education, 50:5, 657-672, DOI: 10.1080/0305764X.2020.1754763

[6]Dweck, C. S. (1999). *Self-theories: Their role in motivation, personality, and development*. New York: Psychology Press.

[2]Higher Education Research Institute. (2010). *Degrees of Success: Bachelor's Degree Completion Rates Among Initial STEM Majors*. Los Angeles: Author.

[7]Huang, G., Taddese, N., and Walter, E. (2000). *Entry and Persistence of Women and Minorities in College Science and Engineering Education* (NCES 2000-601). National Center for Education Statistics, U.S. Department of Education. Washington, DC.

[15]Knekta, E., Rowland, A. A., Corwin, L. A., & Eddy, S. (2020). Measuring university students' interest in biology: Evaluation of an instrument targeting Hidi and Renninger's individual interest. *International Journal of STEM Education*, *7*, 1-16.

[11]Kokkelenberg, E.C., and Sinha, E. (2010). Who Succeeds in STEM Studies? An Analysis of Binghamton University. *Economics of Education Review*, 29(6): 935– 946.

[3]Lowell, B.L., Salzman, H., Bernstein, H., and Henderson, E. (2009, November 7). *Steady as She Goes? Three Generations of Students Through the Science and Engineering Pipeline*. Paper presented at the Annual Meetings of the Association for Public Policy Analysis and Management, Washington, DC.

[12]Mendez, G., Buskirk, T.D., Lohr, S., and Haag, S. (2008). Factors Associated With Persistence in Science and Engineering Majors: An Exploratory Study Using Classification Trees and Random Forests. *Journal of Engineering Education, 97*(1): 57–70.

[4]National Science Board (NSB). (2012). *Science and Engineering Indicators 2012*. Arlington, VA: National Science Foundation.

[13]Shaw, E.J., and Barbuti, S. (2010). Patterns of Persistence in Intended College Major With a Focus on STEM Majors. *The National Academic Advising Association Journal, 30*(2): 19−34.

[14]Strenta, C., Elliot, R., Adair, R., Matier, M., and Scott, J. (1994). Choosing and Leaving Science in Highly Selective Institutions. *Research in Higher Education, 35*(5): 513−547.

[8]Walton, G.M. & Cohen, G. L. (2007). *A question of belonging: Race, social fit, and achievement*. J. Pers. Soc. Psychol. *92*, 82–96.

[9]Whalen, D.F., and Shelley, M.C. (2010). Academic Success for STEM and Non-STEM Majors. *Journal of STEM Education, 11*(1,2): 45−60.

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Lessons Learned from the First Five Years of VolsTeach for Appalachia: Teacher Recruitment of Pre-Service STEM Community College Students

Nick Kim, Carlos Gonzalez & Lynn Hodge (University of Tennessee-Knoxville)

Introduction The VolsTeach for Appalachia (VFA) program is a NSF funded grant project focusing on strengthening the STEM teacher pathway from community college (CC) to East Tennessee high-need school districts. VFA prioritizes community, personal growth, and the importance of equity and diversity in education. The VFA Noyce Scholars are composed of preservice STEM teachers who have backgrounds in community college education ranging from associates degrees to multiple CC classes to dual enrollment courses from high school.

The VFA scholars appreciate their experiences within diverse settings, collaborations with peers, and the opportunity to make a positive difference as future teachers. The scholars believed that the program encouraged a strong sense of community and valued personal experiences with diverse backgrounds. Scholars emphasized meeting future students' needs, advocating for them, and providing access to resources. Scholars achieved success in their classes and the VFA program, demonstrating growth, transition, time management, and involvement in research and internships.

Research questions Specifically, two research questions were targeted in this study

1. What are the areas of strength found within the first five years of this NSF VFA grant?

2. What are the areas to strengthen found within the first five years of this NSF VFA grant?

Methodology and Timeline During the five years of the VFA project program, artifacts including monthly steering committee notes, recruitment materials, focus group interviews with VFA scholars during the academic year, and focus group interviews with new VFA scholars as they participated in a month-long internship focusing on leading middle school and high school summer STEM camps were collected and analyzed for major themes. Monthly steering committee meetings were used three to four times per semester in order to deliver updates and changes to our committee members. Recruitment materials were redesigned and sent out each year. Focus group interviews occurred once a semester to evaluate how VFA scholars were excelling within their education classes as well as suggestions for areas of improvement within the program and curriculum. Lastly, a focus group interview was conducted after their summer induction internship every year for new VFA scholars.

Data Analysis & Results A utilization-focused evaluation approach (Patton, 2012) was employed to evaluate where the data is collected, analyzed, and reported formatively to stakeholders. Data collection methods include a mixed-methods approach (Creswell, 2015) where qualitative and quantitative data are collected and layered to provide a detailed description of project elements. The evidence gathered as to the outcomes and values contribute to the sustainability of the project.

Conclusion The areas of strength for the VFA project included but were not limited to scholars feeling that the program offered them a chance to give back to the community through service learning events. Scholars felt that VFA is an inclusive space to have discussions about diversity and cultures. Those scholars who attended and presented at national conferences enjoyed presenting their research on culturally relevant pedagogy. They appreciated how confident they were in their preparation of their posters. They also learned a lot from the workshop sessions and keynote speakers.

Other areas of strength resulted from their internship experience. Interns learned the most from creating, planning, and implementing their STEM activities for a variety of different age groups. Interns learned a lot from guest speakers who held question and answer sessions but also provided feedback to the activities they created. Interns really appreciated being able to prepare and conduct the activities they created with fellow peers in order to find the strengths and weaknesses of their activity. Lastly, interns expressed their appreciation of the opportunities to engage in discovery and inquiry based learning.

The areas to strengthen included establishing a mentor program before their student teaching requirement. Another area would be to find even more teaching opportunities whether formal or informal in which they could practice teaching with real students. Another area mentioned was the diversity of the VFA scholars, they felt the need to have more representation of different cultures within their cohorts. Finally, VFA scholars yearn for more discussion on how to deal with local issues such as the recent gun violence incidents since they work with diverse populations who face these issues in their lives.

References

Creswell, J. W. (2015). A concise introduction to mixed methods research. Thousand Oaks, CA: Sage Publications

Patton, M. Q. (2012). Essentials of utilization-focused evaluation. Thousand Oaks, CA: Sage Publications..

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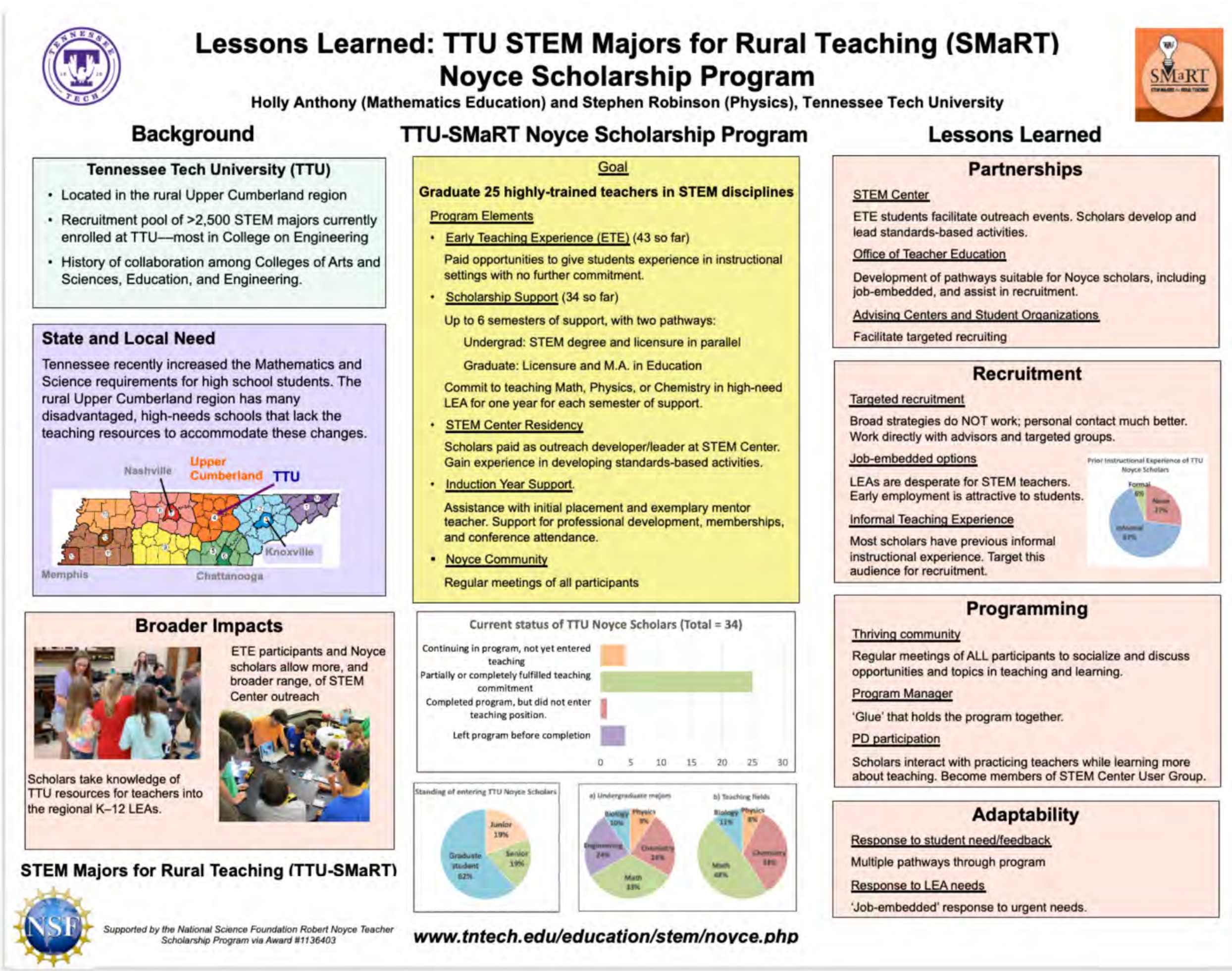
Lessons Learned: TTU STEM Majors for Rural Teaching (SMaRT) Noyce Scholarship Program

Holly Anthony & Stephen Robinson (Tennessee Tech University)

Abstract The Tennessee Technological University – STEM Majors for Rural Teaching (TTU-SMaRT) Noyce Scholarship Program aims to produce highly qualified teachers of mathematics, physics and chemistry to help address the high demand for STEM educators nationally. To date, over 40 STEM majors have participated in the Early Teaching Experience (ETE) internship, 20 STEM majors have been supported by Noyce scholarships, 15 of who have entered a teaching position. Students in the TTU-SMaRT program's ETE internship help facilitate STEM community/outreach activities, exploring whether teaching is a career they wish to pursue. We share strategies that we have implemented with Noyce participants over the past 9 years to ensure their successful induction into the teaching program. Through interviews, observations, and open-response surveys, we have learned what strategies are most impactful.



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Meaningful Mathematics with Coding - Teacher Training and Collaboration with incorporating Computer Science Principles in High School Mathematics

Emily McDonald (Hamilton County Schools & University of Tennessee-Knoxville)

Abstract This research project aims to support high school math teachers within my district in incorporating computational thinking by providing professional development using the TI Innovator Rovers with graphing calculators that have Python abilities. The TI Innovator Rover is a robotics platform that combines the functionality of a graphing calculator with a programmable robot. Through a series of summer professional development sessions and teacher collaborations, participating teachers will learn how to integrate programming and robotics into their high school math curriculum, with a specific focus on Algebra 1, Geometry, and Algebra 2. This project will focus on providing teachers with the skills and knowledge to create engaging, student-centered lessons that help students develop a deeper understanding of mathematical concepts. This project will also investigate the impact of this training on student outcomes, including engagement, achievement, and attitudes toward math and coding. The goal of this project is to determine if this training and collaboration helped their students learn programming capabilities to understand math concepts and build skills in logic, reasoning, and problem-solving skills. The findings of this study will provide insights into the effectiveness of integrating coding and robotics into math classes and the potential for this approach to improve student learning and engagement in STEM subjects.

This research project will be accompanied by the following phases:

● **Phase 1 - Recruitment and Initial Outlook**: Promote this professional development opportunity within my district to recruit a maximum of 15 high school teachers. Participating teachers take a brief survey gauging their initial outlooks on integrating coding in their classroom and their general outlook on integrating STEM in their lessons.

● **Phase 2 - Teacher Professional Development/Training**: During summer training, teachers will be provided the equipment, knowledge, and support to implement a math lesson that incorporates coding using the specific calculator and Rover.

● **Phase 3 - Lesson Implementation**: Teachers will implement a sample lesson, similar to what was implemented at the training. Then, teachers will create their own lesson that uses coding in math.

● **Phase 4 - Data Collection**: Both teachers and students will be surveyed about the experience and learning outcomes will be identified through pre- and post-testing. If needed, the participating teachers will be interviewed for more clarification and insight after the survey. The teacher-created lesson will be analyzed for alignment to state content standards and application.

● **Phase 5 - Mixed Method Data Analysis:**

○ Qualitative: The open-ended responses from the students' surveys will be analyzed to determine students' outlook on mathematics, and the teacher interviews will be analyzed for themes around incorporating computational thinking in their lessons.

○ Quantitative: The pre- and post-test questions will be used to measure and quantify student achievement and Likert scale responses. The supplies for this project are funded through a grant from a community non-profit organization.

Prior Research Around Computer Science in Mathematics

Bråting, K., & Kilhamn, C. (2021). Exploring the Intersection of Algebraic and Computational Thinking. Mathematical Thinking and Learning: An International Journal, 23(2), 170–185.

● This article explores the similarities and differences in the ways of thinking required in the fields of mathematics and computer science.
● Sweden has incorporated programming through algebra for all grade levels.
● There is a need for more research around the differences between algebraic thinking, algorithmic thinking, and computational thinking.

Dohn, N. B. (2020). Students' Interest in Scratch Coding in Lower Secondary Mathematics. British Journal of Educational Technology, 51(1), 71–83.

● Coding is a vital part of technology literacy in today's world.
● The goal of this project was to determine the effect coding had on the student's interest in coding and mathematics.
● The results of this study show a slight negative effect on students' interest in coding due to the level of difficulty and the tedious workflow.

Kaufmann, O. T., & Stenseth, B. (2021). Programming in Mathematics Education. International Journal of Mathematical Education in Science and Technology, 52(7), 1029–1048.

● Highlights how programming skills are more important than ever as many school, district, and state focus on the implementation of programming in school curriculum.
● Prior literactive has examined the connection between mathematics and programming where programming can contribute to mathematics education.
● The focus of this research study was on how lower secondary school students apply programming thinking when working with a mathematical problem.

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Measuring Goal Alignment within a Community of Research Teams

Thomas Stiles (University of Montana Western)

Significance The community of practice framework (Lave & Wenger, 1991) has served as an interpretative framework for numerous qualitative studies on undergraduate research but has rarely been operationalized for quantifying learning processes within undergraduate research communities (Murillo, 2011). Mutual engagement, joint enterprise and shared repertoires are said to be hallmark practices of learning communities; and yet we still lack tools for measuring their prevalence. Mutual engagement is of particular interest for understanding research communities in which novice undergraduates join teams mentored by faculty and more advanced students. Mutual engagement has been described as a goal alignment process through which novice undergraduates match their career interests to projects goals (Desai et al., 2008). To quantify the level of goal alignment experienced by individuals, memories of team goal discussions could be examined (Iverson & McPhee, 2008). This study's purpose is to assess approaches to measuring the goal alignment that occurs when undergraduates join and work in a research community.

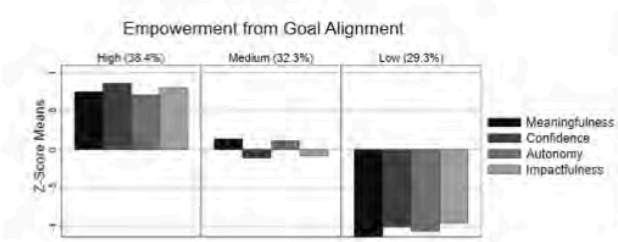
Background Figuring out how to quantify the goal alignment process would help us understand the way university research communities support undergraduate career development. To investigate this further, undergraduate researchers were recruited from a community of STEM research teams. To join this community, undergraduates contacted student team leaders and faculty mentors and then negotiated their role in the research project. Because there are no monetary incentives or time requirements, an undergraduate's role on the team is negotiated as participants decide how to pursue the team's project goals. Unlike many apprenticeship programs, (Lopatto, 2007; Russell et al., 2007), this research community program has no selection criteria and helps all students join a team. Consequently, students have a diverse array of career development goals (Author).

Measuring the prevalence of goal alignment that occurs during a semester could be approached in a couple of different ways. Undergraduates could be asked how often their team talked about their research interests relative to project goals. Alternatively, undergraduates could be asked to evaluate the meaningfulness of project goal discussions, the autonomy they had in discussing project goals, the confidence they had in managing project goals, and the impact they had on project goals (Spreitzer, 1995; Thomas & Velthouse, 1990). Taken together, these evaluations can be used to model the empowerment that discussions of personal and team goals provided students. This construct of empowerment is neither an enduring or global personality trait, but rather a context-specific measure of intrinsic task motivation (Spreitzer, 1995). Applying this construct to the goal alignment occurring in research teams, however, requires us to develop and validate a new set of survey questions.

Question To study how a university research community might influence the career development aspirations of undergraduates, efficient measurement tools need to be constructed and validated. The main question is whether a few direct survey items on how often discussions of team member interests and team project goals occur would be sufficient. Or whether an empowerment model is necessary to gauge the influence of goal alignment on the intrinsic motivation of undergraduates to participate in project work. This question can be evaluated by testing whether the frequency of goal alignment discussions are independent from the empowerment felt by undergraduates.

Analysis Methods Survey data was collected from undergraduates participating in a team research community for the first time over eight semesters (n = 426). Direct questions were asked about how often project goals and team member interests were discussed. Responses included once or twice (1) every week, (2) every few weeks, or (3) during the semester. Specific ways project goals were aligned with team member interests. The survey also asked Likert-scale questions to evaluate the meaningfulness, confidence, autonomy, and impact that undergraduates felt they had on team project goals. Confirmatory factor analysis was performed on these subscale items to evaluate the empowerment construct. Cluster analysis was then performed to evaluate subscale patterns and classify subjects according their empowerment level in project work. Cramer's V was used to test how strongly the frequency and empowerment of goal alignment were associated.

Key Findings Confirmatory factor analysis indicated the four empowerment subscales (i.e., meaningfulness, autonomy, satisfaction, and impactfuless) was a good fit for collected goal alignment data ($n = 426$, $\chi 2 = 95.6$, $df = 48$, $p < 0.0001$, RMSEA=0.048, CFI=0.984, SRMR=0.027). Fit indices conformed to standard cutoff criteria (Hu & Bentler, 1999). Subscale z-score means appeared relatively equivalent across cluster solutions. Cluster solutions with three to six levels had a mean explained variance greater than 50%. The three level cluster solution is shown below. Also shown are the associations this empowerment variable has with the frequencies that project goals and team member interests were discussed. Strength is interpreted with standard criteria (Cohen, 2013).



Frequency	Cramer's V	Association ($df = 2$)
Talk about improving project goals	0.2801	Modest
Talk about addressing team member's interests	0.3188	Modest

Conclusions Cultural models of situated learning have provided useful frameworks for conceptualizing social processes, but have yet to be sufficiently operationalized to evaluate how these processes can influence the outcomes of undergraduate research. This study was undertaken to investigate whether direct survey questions about the frequency of team project goals and team member interest discussions would be sufficient for evaluating goal alignment levels in a research community of teams. The findings shown above suggest there are statistically modest associations between how often project goals and team member interests are discussed and the team member sense of empowerment from those discussions. These findings do not make a strong case for using frequency questions to evaluate goal alignment. Rather, these findings suggest that a study's conceptual framework should be considered when considering a measurement approach. In the case that the perceived empowerment from goal alignment is more appropriate, this study does provide offer researchers a measurement tool that can be administered relatively quickly.

References

Author
Cohen, J. (2013). Statistical power analysis for the behavioral sciences. Academic press.
Desai, K. V., Gatson, S. N., Stiles, T. W., Stewart, R. H., Laine, G. A., & Quick, C. M. (2008).

Integrating research and education at research-extensive universities with research-intensive communities. Advances in Physiology Education, 32(2), 136-141.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal, 6(1), 1-55.

Iverson, J. O., & McPhee, R. D. (2008). Communicating knowing through communities of practice: Exploring internal communicative processes and differences among CoPs. Journal of Applied Communication Research, 36(2), 176-199.

Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. CBE—Life Sciences Education, 6(4), 297-306.

Murillo, E. (2011). Communities of practice in the business and organization studies literature. Information Research, 16(1), 1.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. Science, 316(5824), 548-549.

Spreitzer, G. M. (1995). Psychological empowerment in the workplace: Dimensions, measurement, and validation. Academy of Management Journal, 38(5), 1442-1465.

Thomas, K. W., & Velthouse, B. A. (1990). Cognitive elements of empowerment: An "interpretive" model of intrinsic task motivation. Academy of management review, 15(4), 666-681.

Goal Alignment Survey Questions

Frequency

GA1 How frequently has your team talked about how to improve project goals?
GA2 How frequently does your team talk about your interests in how to improve project goals?
GA3 Can you identify specific ways that that project goals were improved to better align with your own interests?

Meaningful

GAM1 Team members like me appreciate how we have been included in discussions about how to improve project goals. GAM2 After talking with others about how to improve project goals, my participation became more meaningful to me.
GAM3 My own curiosities and interests align well with what others on the team have said about how to improve project goals.

Autonomy

GAA1 My team and I have had considerable freedom to discuss our concerns about how to improve project goals. GAA2 Team members like me have a lot of opportunities to discuss how to improve project goals.
GAA3 The project has allowed time for team members and me to discuss and reconsider how to improve project goals.

Confidence

GAC1 I usually raise critical questions and sometimes challenge what others say about how to improve project goals.

GAC2 Because I understand how to improve project goals, I get involved in talking with others about what we should do next. GAC3 Even if my own ideas did not work, I am confident that I could contribute to team discussions to improve project goals.

Impactful

GAI1 I have significant influence in team conversations about how to improve project goals.
GAI2 I am able to have a large impact on how to improve project goals by talking to other members of the team.
GAI3 I participate in conversations about how to improve project goals because I am able to influence the direction of the project.

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Metacognition in Assessing Evolutionary Understanding: A Consideration

Rahmi Aini & M. Elizabeth Barnes (Middle Tennessee State University)

Background of the study Evolution is a foundational explanatory framework for biology and a core concept that biology students should learn in their development as scientific thinkers (AAAS, 2011; Brownell et al., 2014). However, studies reported that students often have a poor understanding of evolution (Pobiner, 2016; Rissler et al., 2014; Wingert et al., 2022, 2022). Students' epistemological belief (Sinatra et al., 2014) and intuitive cognition (Ha et al., 2012) factors have been suggested as contributing to the difficulties students face in understanding evolution. Epistemological beliefs refer to how students understand knowledge acquisition, determine what is true, and how one can ascertain the validity of information (Buratti et al., 2017; Sinatra et al., 2014). Intuitive cognition, on the other hand, is a term used to describe confidence in students' understanding of a particular concept (Ha et al., 2012). For instance, Ha et al. (2012) found that students' intuitive cognition, measured by students' confidence in their understanding of evolution, moderates the relationship between students' acceptance and understanding of evolution. This intuitive cognition is a nonconscious process that increases their confidence in their own knowledge. Therefore, it is important for students to be aware of what they know about evolution, how they evaluate scientific evidence, and how they know what they know.

The current study aims to differentiate between students' cognitive performance (knowledge of evolution) and their self-assessment of their performance (confidence in understanding). Knowing students' confidence in their own knowledge is also beneficial for identifying concepts for which students have misconceptions or if they simply lack knowledge (Potvin, 2023). The Biological Evolution Literacy Survey can be used to assess students' understanding of evolution and identify common misconceptions (Yates & Marek, 2013, 2014). This survey consists of 23 statements to measure knowledge of evolution and its relation to the acceptance of evolution. In the original survey, participants rated their agreement level in each item on a 7-point scale. Disagreeing with a scientifically correct statement may indicate a rejection of supporting evidence and a lack of understanding. These assumptions are reflected in the concept of epistemological belief, which suggests that measuring students' understanding also provides insights into their agreement with the scientific information. However, this instrument lacks some validity evidence (Mead et al., 2019; Tornabene et al., 2018).

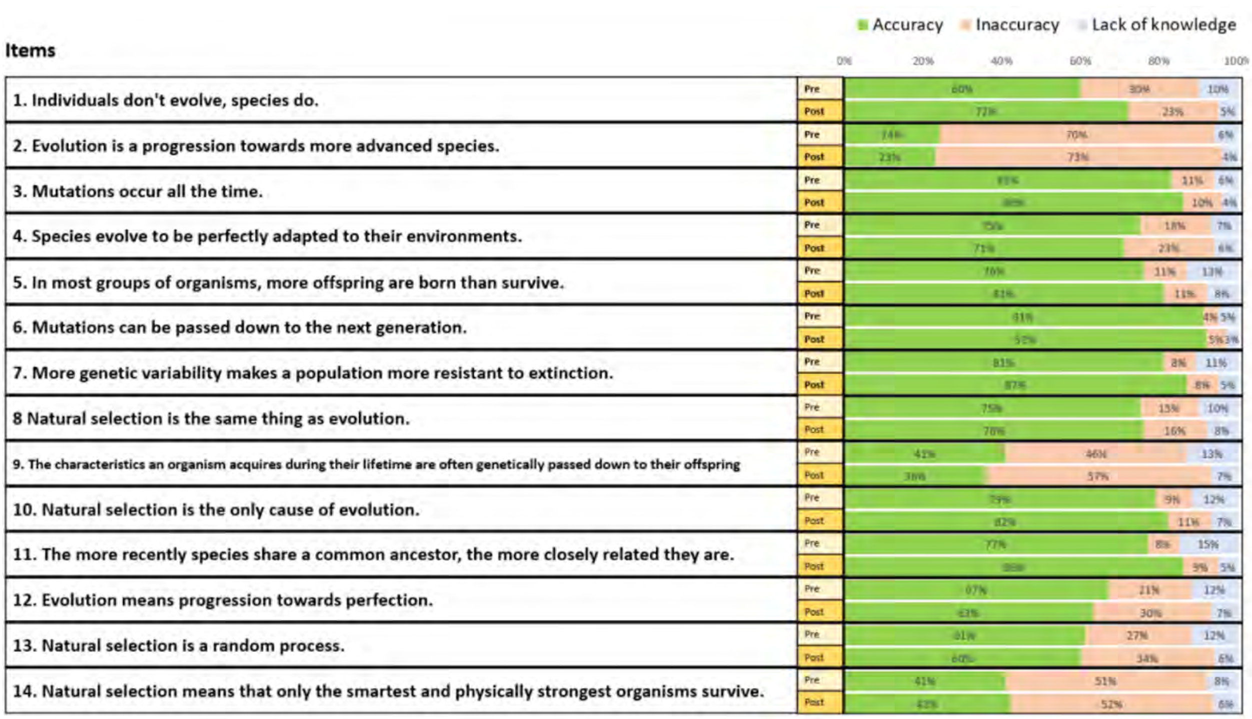
It is important to note that agreeing with a statement does not necessarily indicate a comprehensive understanding of the topic, and ambiguous agreement scores can make it challenging to interpret assessment results accurately. To address these issues, we changed the response format to three discrete options ("True", "False", or "I don't know enough to answer") which consider students' reflective processes when monitoring knowledge about evolution. The research questions in this study are:

1) How does the calibrated evolution understanding metacognitive monitoring score differ from the traditional evolution understanding score?

2) Which evolutionary concepts in the EALS instrument are associated with misconception? and 3) What is the difference in understanding before and after learning?

Data analyses and procedures The study involved 2622 students from 18 introductory biology courses in 11 states during Fall 2022 and Spring 2023. The EALS-instrument was used to measure students' comprehension of evolution before and after watching a 15-minute video lecture. We modified the scoring based on the instrument format, assuming that students had confidence in their knowledge when they could provide accurate true or false responses. The accuracy scores were determined by evaluating the students' ability to assess a statement as true or false confidently and correctly, while the 2 inaccuracy by misconception scores was determined when students demonstrated confidence in their judgment despite providing incorrect responses. Furthermore, the lack of knowledge scores was determined by the number of uncertain responses.

Analyses and Preliminary Result Overall, the scoring for metacognitive resulted in a more normal distribution compared to the traditional scoring. Using this score is then more beneficial because it allows for the use of many common statistical tests that require normality assumptions. Additionally, the bell-shaped curve with the majority of data points clustering around the mean makes it easier to interpret and compare different sets of data. Additionally, metacognitive monitoring scores also showed three different properties of students understanding.



The average proportion of "lack of knowledge" responses decreased after students learned about evolution. However, three items (2, 9, and 14) were found to have over 50% of students holding inaccurate understandings before and after learning about evolution. These items include the misconception that evolution is a progression towards more advanced species, the belief in the inheritance of acquired characteristics, and an informal explanation of natural selection.

This is concerning as it suggests that students are confident in their inaccurate understanding despite holding inaccurate concepts Moreover, there was an increase in inaccuracy after learning. For instance, students' confidence in the misconception that natural selection is a random process (item 13) and the belief that species evolve to be perfectly adapted to their environments (item 4) increased. Prior research has identified five ambiguous terms in evolutionary explanations, including "pressure," "select," "adapt," "need," and "must" (Rector et al., 2013). This study also suggests that students may use inappropriate evolutionary language, such as "random" (item 13), which requires further investigation. The next step of this research is item analysis and compare other demographic information such as religious identity or level of evolution acceptance to see if the changes are generalizable across undergraduate biology students. 3

References

American Association for the Advancement of Science. (2011). *Vision and Change in Undergraduate Biology Education*. https://visionandchange.org/finalreport/

Barnes, M. E., & Brownell, S. E. (2017). A call to use cultural competence when teaching

evolution to religious college students: Introducing religious cultural competence in evolution education (ReCCEE). *CBE—Life Sciences Education*, *16*(4), es4. https://doi.org/10.1187/cbe.17-04-0062

Brownell, S. E., Freeman, S., Wenderoth, M. P., & Crowe, A. J. (2014). BioCore Guide: A Tool for Interpreting the Core Concepts of Vision and Change for Biology Majors. *CBE—Life Sciences Education*, *13*(2), 200–211. https://doi.org/10.1187/cbe.13-12-0233

Ha, M., Haury, D. L., & Nehm, R. H. (2012). Feeling of certainty: Uncovering a missing link between knowledge and acceptance of evolution. *Journal of Research in Science Teaching*, *49*(1), 95–121. https://doi.org/10.1002/tea.20449

Ha, M., Wei, X., Wang, J., Hou, D., & Nehm, R. H. (2019). Chinese pre-service biology teachers' evolutionary knowledge, reasoning patterns, and acceptance levels. *International Journal of Science Education*, *41*(5), 628–651. https://doi.org/10.1080/09500693.2019.1572936

Heddy, B. C., & Nadelson, L. S. (2013). The variables related to public acceptance of evolution in the United States. *Evolution: Education and Outreach*, *6*(1), 3. https://doi.org/10.1186/1936-6434-6-3

Mead, L. S., Kohn, C., Warwick, A., & Schwartz, K. (2019). Applying measurement standards to evolution education assessment instruments. *Evolution: Education and Outreach*, *12*(1), 5. https://doi.org/10.1186/s12052-019-0097-y

Nelson, C. E., Scharmann, L. C., Beard, J., & Flammer, L. I. (2019). The nature of science as a foundation for fostering a better understanding of evolution. *Evolution: Education and Outreach*, *12*(1), 6. https://doi.org/10.1186/s12052-019-0100-7

Pobiner, B. (2016). Accepting, understanding, teaching, and learning (human) evolution: Obstacles and opportunities. *American Journal of Physical Anthropology*, *159*(S61), 232–274. https://doi.org/10.1002/ajpa.22910

Potvin, P. (2023). Response of science learners to contradicting information: A review of research. *Studies in Science Education*, *59*(1), 67–108. https://doi.org/10.1080/03057267.2021.2004006

Rector, M. A., Nehm, R. H., & Pearl, D. (2013). Learning the Language of Evolution: Lexical Ambiguity and Word Meaning in Student Explanations. *Research in Science Education*, *43*(3), 1107–1133. https://doi.org/10.1007/s11165-012-9296-z

Rissler, L. J., Duncan, S. I., & Caruso, N. M. (2014). The relative importance of religion and education on university students' views of evolution in the Deep South and state science standards across the United States. *Evolution: Education and Outreach*, *7*(1), 24. https://doi.org/10.1186/s12052-014-0024-1

Sinatra, G. M., Kienhues, D., & Hofer, B. K. (2014). Addressing Challenges to Public Understanding of Science: Epistemic Cognition, Motivated Reasoning, and Conceptual Change. *Educational Psychologist*, *49*(2), 123–138. https://doi.org/10.1080/00461520.2014.916216

Tornabene, R. E., Lavington, E., & Nehm, R. H. (2018). Testing validity inferences for Genetic Drift Inventory scores using Rasch modeling and item order analyses. *Evolution: Education and Outreach*, *11*(1), 6. https://doi.org/10.1186/s12052-018-0082-x

Wingert, J. R., Bassett, G. M., Terry, C. E., & Lee, J. (2022). The impact of direct challenges to student endorsement of teleological reasoning on understanding and acceptance of natural selection: An exploratory study. *Evolution: Education and Outreach*, *15*(1), 4. https://doi.org/10.1186/s12052-022-00162-6

Yates, T. B., & Marek, E. A. (2013). Is Oklahoma really OK? A regional study of the prevalence of biological evolution-related misconceptions held by introductory biology teachers. *Evolution: Education and Outreach*, *6*(1), 6. https://doi.org/10.1186/1936-6434-6-6

Yates, T. B., & Marek, E. A. (2014). Teachers teaching misconceptions: A study of factors contributing to high school biology students' acquisition of biological evolution-related misconceptions. *Evolution: Education and Outreach*, *7*(1), 7. https://doi.org/10.1186/s12052-014-0007-2

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Parent's Early Home Math Support Does Not Correlate between Survey and Interview Responses

Brooke Poston, Camille Msall, Ashli-Ann Douglas, Bethany Rittle-Johnson

Introduction Four-year-olds' early math knowledge, specifically numeracy and patterning skills, is important for later math achievement (3, 8). Specifically, strong correlations have been found between preschool math ability and adolescent academic success (10). The support that they receive is crucial to making this happen, especially at home. Much of the current research on preschoolers' math skills examines the support that kids get from their parents, through measures of the frequency of parental support through the reported math activities they engage, in and the complexity of this support, or the frequency of support for advanced skills (1, 2, 5, 6). Frequency is important in signifying how much exposure preschoolers get, and complexity is important for exposure to advanced skills. Research with these common measures have found that the home environment is extremely influential on children's skills in early math development (1, 2, 9). However, parents report not feeling comfortable helping their children with math, and often have to teach themselves using the materials that come home from the school (4). If we can find ways to support parent learning, these kids will be better supported in their current and future mathematical development.

Research Questions 1. What kinds of math support do parents report engaging in with their four-year-olds at home? 2. What examples of their math support do parents provide during an information session? Does the number of provided examples correlate to the frequency or complexity of parent math support?

Methodology

Participants

Participants were 107 parents (85% mothers) and their four-year-old children (49.5% sons) in Nashville and the sessions occurred at drop off or pick up at a quiet place in their child's school, or on Vanderbilt campus. Inclusion criteria required that parents and children spoke English, and that the child did not receive any special education services. Most parents (53%) reported a household income of 90,000 or more, and 44% of parents reported a graduate degree. Additionally, 54% of the parents identified as Caucasian, 36% as African American/Black, 2% as Asian or Pacific Islander, 3% as Biracial/Mixed Race, 4% as Other Race, and 1% said "I am unsure" or "I prefer not to say."

Procedure

Parents received a $50 gift card for completing the two-session study. In the current study, we focus on the first session only. Each participant completed a parent survey and participated in a parent-child play session for 5 minutes. Afterward, the child played with another experimenter while the parent participated in an information session about four patterning or numeracy skills, based on random assignment. The information session was video-recorded for coding purposes.

Measures

Frequency and Complexity of Math Support Adapted from Zippert and colleagues (11), parents reported how often they engaged in numeracy activities (n = 16) in the previous two weeks on a 6-point scale from 0 = never to 5 = daily. Parents reported how frequently they engaged in patterning activities (n = 15) in the previous two weeks on a 5 point scale, from 0 = never and 4 = daily. Parents also reported on spatial activities (n = 7) as distractors. Averages were calculated to create the frequency of their support (overall average rating) and complexity of their support (average rating for advanced skills).

Info Session Skills During the Info Session, parents heard information about four patterning or numeracy skills based on random assignment to condition. The four patterning skills were missing part of a pattern, copying a pattern, extending a pattern, and abstracting a pattern. The four numeracy skills were cardinality, numeral identification, magnitude comparison, and arithmetic. These skills were the focus of the intervention due to their relevance to four-year-olds' math development and were designed to connect to the activities rated in the survey (5, 7). For each skill, parents were asked to provide an example of how they engage in the skill at home.

Data Analysis & Results From video recordings, we transcribed the examples parents gave in the information session. One author and two additional researchers divided the participants, coded the examples that parents gave into categories, and discussed disagreements until a decision was reached. In the end, thirteen categories were agreed upon.

We found the most common category for each skill, as well as its frequency. Common categories included using toys, food, or home items for math support, with toys being the most common for four of the eight skills across conditions. We ran correlations to examine the relationship between the frequency or complexity of parents' reported support, and each question's most common category for numeracy and patterning skills. Numeracy correlations varied widely by skill for frequency (r = .03, .08, .12, .10) and complexity (r = -.06, .23, .17, .07), but were nonsignificant. Pattern correlations also varied widely by skill for frequency (r = -.04, .02, .04, -.09) and complexity (r = .05, .05, .14, .02), but were nonsignificant.

Discussion & Conclusions The current study tells us what parents are already doing, and we can see that toys are most commonly used to practice mathematics skills in the home. The open-ended nature of the examples also helps to find gaps in parents' practices where additional support for parents may be beneficial. Although some skill examples showed weak positive correlations, they did not correlate with the frequency or complexity of their support. One explanation is parents often gave general examples (e.g. toys), instead of specific activities like in the survey (e.g. "compare the cost of items in a grocery store"). One limitation is activities were self-reported on the survey, while the specific examples were provided verbally, directly to the experimenter. Another is the immediacy of the questions. Perhaps in another format, instead of an on-the-spot interview, parents might give answers that align more with their survey answers.

Finally, this type of information session in the current study has implications for how schools can easily communicate strategies to parents to give them ideas on how they can help their child. Future research should examine if an information session can help to build their confidence in mathematics and even change their math support.

References

Berkowitz, T., Schaeffer, M. W., Maloney, E. A., Peterson, L., Gregor, C., Levine, S. C., & Beilock, S. L. (2015). Math at home adds up to achievement in school. *Science, 350*(6257), 196–198.

Elliott, L., & Bachman, H. J. (2017). How do parents foster young children's math skills? *Child Development Perspectives*, *12*(1), 16–21.

Fyfe, E. R., Rittle-Johnson, B., & Farran, D. C. (2019). Predicting success on high-stakes math tests from preschool math measures among children from low-income homes. *Journal of Educational Psychology*, *111*(3), 402–413. https://doi.org/10.1037/edu0000298

Ginsburg, L., Rashid, H., & English-Clarke, T. (2008). Parents learning mathematics: For their children, from their children, with their children. *Adult Learning*, *19*(3), 21–26.

Litkowski, E. C., Duncan, R. J., Logan, J. A. R., & Purpura, D. J. (2020). When do preschoolers learn specific mathematics skills? Mapping the development of early numeracy knowledge. *Journal of Experimental Child Psychology*, *195*(8), 1–25.

Napoli, A. R., Korucu, I., Lin, J., Schmitt, S. A., & Purpura, D. J. (2021). Characteristics related to parent-child literacy and numeracy practices in preschool. *Frontiers in Education*, *6*, 1–9.

National Research Council. (2009). *Mathematics learning in early childhood: Paths toward excellence and equity* (C. T. Cross, T. A. Woods, & H. Schweingruber, Eds.). National Academies Press.

Rittle-Johnson, B., Zippert, E. L, & Boice, K. L. (2019). The roles of patterning and spatial skills in early mathematics development. *Early Childhood Research Quarterly*, 196–199. https://doi.org/10.1016/j.ecresq.2018.03.006

Skwarchuk, S. (2009). How do parents support preschoolers' numeracy learning experiences at home? Early Childhood Education, 37(3), 189–197.

Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Educational Researcher*, *43*(7), 352–360.

Zippert, E. L., & Rittle-Johnson, B. (2020). The home math environment: More than numeracy. *Early Childhood Research Quarterly*, *50*(3), 4–15. https://doi.org/10.1016/j.ecresq.2018.07.009

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Parental Mathematics Support Through Pattern Activities and Talk

Alexis Richmond, Camille Msall, Ashli-Ann Douglas, Faith Logan & Bethany Rittle-Johnson (Vanderbilt University)

Abstract Children learn and develop a wide range of mathematical skills before they ever step foot into formal schooling. One important environment where this learning often takes place is coined the “home math environment”, which encompasses parents’ support for their child’s numeracy, patterning, and spatial skills at home (Zippert & Rittle-Johnson, 2020). Previous research has examined parents' support through parent-reported activities and parent-child talk during play. Specifically, parents report engaging with their child in activities that focus on numeracy skills multiple times a week. However, parents tend to spend less time on pattern skills, on average only one to three times a month (Zippert et al., 2020). Similarly, parents tend to spend at least some talk during play on numeracy skills while patterning talk occurs less frequently (Zippert et al., 2019; Zippert et al., 2020). This is contrary to previous research that pattern knowledge, or predictable sequences of elements that repeat and can go on infinitely, is important for future mathematical success (Rittle-Johnson et al., 2015; Fyfe et al., 2017; Rittle-Johnson et al., 2019).

In addition to overall support, previous research has examined the complexity of support, or frequency of support for advanced skills. Typically, advanced patterning talk includes extending a pattern (adding on to the end of a pattern), abstracting (creating the same pattern with different materials), or identifying the pattern unit (identifying the red-blue unit in a red-blue-red-blue pattern) (Zippert et al., 2020). Similarly, pattern activities that parents report engaging in with their children are also categorized as advanced activities.

While the limited previous research has identified a hierarchy of patterning skills, research on patterning skills is still understudied. As a part of a larger intervention study focused on the patterning and numeracy support that parents provide their children, the current research specifically analyzed parents’ reported and observed patterning support in the patterning condition, who participated in an information session about four patterning skills four-year-olds can learn, before their information session (session one) and two weeks later (session two).

Research Questions

4. Do parents use more pattern talk at session two than they did at session one?
5. Do parents who report doing pattern activities more frequently at home also use more pattern talk during the second play session?
6. Do parents who report doing more complex pattern activities at home also use more complex pattern talk during the second play session?

Methodology and Timeline Participants were 107 parents (85% Mothers) and their 4-year-old child (Mean Age = 4.59, SD = .34; 49.5% Sons) recruited from public and private preschools, and a psychology departmental database of families in Nashville, Tennessee. Participants received a $50 gift card for completing both sessions. Participants were randomly assigned to

one of two conditions for their information session: numeracy or patterning. For the current study, we are only focusing on the patterning condition ($n = 53$). Parents completed a parent survey and parent-child play session in each session and in session 1, also received an info session about four patterning skills
four-year-olds can learn and a series of text messages with facts and tips for these skills over the two weeks between sessions. The parent survey asked parents 15 different questions regarding how often they support different math activities at home on a scale from 1 (never) to 6 (daily). The play sessions were 5 minutes and they played with wooden beads and strings we provided. Sessions were videotaped for coding purposes. After session one's play session, the experimenter gave a 15-minute information session on four patterning skills four-year-olds can learn.

Data Analysis and Results Parents' pattern talk during the play session was coded using a coding scheme adapted from Zippert et al. (2020) and previous research on patterning skills. Codes were hierarchical and mutually exclusive with 10 different patterning skills, ranging from sorting to IDunit. Four researchers coded parent patterning talk divided into 10-second intervals. Four coders double-coded 29% of videos and reliability was met when coders reached kappa = .70 with the primary coder, We had good reliability between the primary coder and each research assistant for parents' patterning talk ($k > .73$).

All analyses were run in SPSS. Averages for parent talk across intervals and reported activities served as overall frequency, and the same averages including on advanced skills were used for complexity. A paired t-test for parent pattern talk indicated a significant difference between the pattern advanced talk at session 1 ($M = .08$, $SD = .11$) and session 2 ($M = .13$, $SD = .13$), $t(52) = -4.70$, $p = < .001$. We also ran two bivariate correlations between the variables for frequency and complexity of parent talk and reported activities. There was a positive relationship between the overall frequency of parent pattern talk and reported activities, but the correlation was not significant, $r(52) = .07$, $p = .62$. There was a positive relationship between the complexity of parent pattern talk and reported pattern activities, but the correlation was not significant, $r(52) = .01$, $p = .96$.

Conclusion Based on our results, we found that our information session was successful in increasing parent pattern talk from session 1 to session 2. Additionally, there were very weak positive correlations between both the frequency and complexity of parent talk and activities, but these were nonsignificant. One potential reason could be that an increased amount of parental support through talk could cause parents to not feel the need to do pattern activities as much. Another plausible reason for the lack of significant correlations could be due to the fact that parents don't have enough time to significantly increase their talk and activities, so they chose one of the other. Importantly, the current study is correlational, and future research should examine causal explanations and mediators that may explain the relationship between parental support. Additionally, this study is just one piece of the home mathematical environment, and future studies should work to understand how pattern knowledge and skills can be supported through a combination of parental talk and activities.

References

Fyfe, E. R., McNeil, N. M., & Rittle-Johnson, B. (2015). Easy as ABCABC: Abstract language facilitates performance on a concrete patterning task. *Child Development*, *86*(3), 927–935. https://doi.org/10.1111/cdev.12331

Rittle-Johnson, B., Fyfe, E. R., Loehr, A. M., & Miller, M. R. (2015). Beyond numeracy in preschool: Adding patterns to the equation. *Early Childhood Research Quarterly*, *31*, 101–112. https://doi.org/10.1016/j.ecresq.2015.01.005

Rittle-Johnson, B., Zippert, E. L., & Boice, K. L. (2019). The roles of patterning and spatial skills in early mathematics development. *Early Childhood Research Quarterly*, *46*, 166–178. https://doi.org/10.1016/j.ecresq.2018.03.006

Zippert, E. L., & Rittle-Johnson, B. (2020). The home math environment: More than numeracy. *Early Childhood Research Quarterly*, *50*, 4–15. https://doi.org/10.1016/j.ecresq.2018.07.009

Zippert, E. L., Douglas, A.-A., Smith, M. R., & Rittle-Johnson, B. (2020). Preschoolers' broad mathematics experiences with parents during play. *Journal of Experimental Child Psychology*, *192*, 104757. https://doi.org/10.1016/j.jecp.2019.104757

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Partnership To Develop Fermentation Science as a Curricular Enhancement to Basic Undergraduate Stem Classes

Tony Johnston, Terry Goodin & Ginger Rowell (Middle Tennessee State University)

Introduction The agriculture industry in the U.S. faces significant challenges, both now and moving forward. As the world population approaches 7.5 billion, food and fiber production are insufficient to meet demands. The premise of this project is that food fermentation will be important to address what is likely a catastrophic threat, and that students need to more aware of the possibilities and options they have related to this vital industry.

Accordingly, agricultural education must focus on ways to ensure that food and fiber are effectively preserved, while at the same time meeting public demands regarding flavor, texture and even cultural expectations. To this end, Middle Tennessee State University established a Bachelor of Science STEM-based degree in Fermentation Science in 2017, focused on fermentation science and applications leading to agricultural products, probiotics, pharmaceuticals, industrial chemicals, and treated wastewater. The degree emphasizes the role that fermentation plays in the economy and in human survival.

U.S. consumers are seeking bolder flavor in their foods, and that demand is being met by fermented foods (Hennessy, 2019). As demand increases, large food companies such as PepsiCo are buying small food producers (Zemser, 2019). Interest in probiotic compounds, produced through fermentation, is also on the rise (Getz, 2019). As the American public learns more about the links between diet and health, demand for trained personnel to work in agriculture with specific knowledge of fermentation will increase.

This ongoing project was undertaken to train STEM teachers at Tennessee's regional community colleges, to incorporate fermentation science-related topics into their existing classes, and to provide options to students to explore the benefits of a career in fermentation science. Local partner institutions include Columbia State Community College (CSCC) and Motlow State Community College (MSCC).

This project employs Problem-Based Learning (PBL) as the primary tool for integrating fermentation science into existing STEM curricula. The pedagogy of PBL has been extensively researched and evidence is now clear that the use of PBL increases student comprehension of course content by using "real-world" problems or scenarios (Goodin & Dillard, In Press). By anchoring STEM concepts to real-world applications, students gain an appreciation of both the scientific concepts and the application of those concepts to solving real-world problems.

PBL development teams consisted of community college faculty members with discipline expertise (Chemistry, Biology) and MTSU co-PIs, faculty members with extensive PBL knowledge, fermentation science faculty members and local industry partners. These individuals collaboratively developed PBL modules in Biology, Chemistry and Math, organized around a fermentation science problem. Community college instructors attended PBL summer workshop training on the MTSU campus where lessons were presented and PBL course materials were disseminated.

The community college faculty identified feasible activities demonstrating key science concepts, while generating interest in fermentation science. Involving community college faculty as stakeholders in this process ensured the curricula and activities developed were not only possible to implement but interesting and desirable to the faculty participants who helped design them. It is expected that these faculty will want to continue using these tools in their classrooms beyond the life of this project.

Research questions This project sought to answer the following research questions:

1. To what extent will community college students recognize Fermentation Science as an educational option as well as a career?

2. How well did community college instructors do in the design of a Problem-Based Learning Module?

3. What reflections did the instructors have regarding the efficacy of the project as it related to their disciplinary content and to Fermentation Science?

Methodology and Timeline A questionnaire will be administered to students which is to reflect their awareness of Fermentation Science as an educational option and career. (Research Question #1)

Observations of instructor behavior during training sessions will be made by project personnel. Developed modules will be examined and compared to the Eight Elements of the PBL Module as developed by project personnel. The results will be discussed. (Research Question #2)

Interviews with community college instructors will be conducted. These will be collected and analyzed using a coding and sorting method to determine emerging themes. (Research Question #3)

The following project activities were designed to directly address the objectives detailed earlier:

1. Create and integrate PBL modules focused on fermentation science into introductory biology, chemistry and mathematics courses. The first phase of this activity has been completed and will be presented. These PBL modules support the experiential learning opportunities that will be directly associated with ongoing research into topics of interest and value to the fermentation industry in Tennessee (e.g. hop variety research, barley for malting research, grape endophyte research).

2. The PBL development teams, consisting of community college faculty members with specific discipline (Chemistry, Biology) expertise and co-PIs, MTeach faculty members with extensive PBL knowledge, fermentation science faculty members and local industry partners met multiple times over the course of the academic year to develop PBL modules. During those meetings, a relevant problem in fermentation science was selected that connects to objectives in Biology,

Chemistry, and/or Mathematics. This Module, entitled "The Legacy," will be presented and discussed. Current work includes the design of anchor videos, laboratory activities, and materials needed for implementation, which will be discussed.

3. Collaborative Interaction with Other Academic Institutions. Building upon the resources available through MTSU's formal and informal collaborations with fermentation-utilizing industries, the team has integrated experiential learning opportunities focused on fermentation science into introductory biology, chemistry and mathematics courses at the community colleges. These experiential learning opportunities were directly associated with ongoing research into topics of interest and value to the fermentation industry in Tennessee (e.g. hop variety research, barley for malting research, grape endophyte research).

Data Analysis & Results Data gathered will be analyzed using a mixed method approach. Quantitative data will undergo standard analysis (e.g. mean, standard deviation, regression) and qualitative data will be analyzed for phrase frequency, intensity, and discipline area.

To date, the project has completed the initial phases of workshops, PBL Module design, and first implementations of the module. The team of instructors and university personnel decided upon a module topic and developed the module for use in the various disciplines. Outcomes are forthcoming.

Conclusion It is expected that ties between the mid-state community colleges and MTSU will have been strengthened (both formally and informally), that faculty at both MTSU and the partner community colleges will have gained significant fermentation science knowledge, and further, that students will have gained the benefit of exposure to practical applications of science and mathematics at the introductory levels of STEM education. Fermentation Science will ultimately have better prepared students to pursue any applied course of study (not just Fermentation, but all STEM) and those choosing to pursue Fermentation Science will be well equipped to succeed in the four-year degree program. Industry partners will also have a higher quality candidate pool as Tennessee will have gained a critical mass of technical expertise in this vital and rapidly expanding field. Finally, the outcomes are expected to support Fermentation Science and will identify associated lines of research.

References

Getz, L. (2019, July 16). Fermented foods—are they the next big nutrition trend?. *Today's Dietician.* 14(7), 52. Retrieved July 16, 2019, from http://www.todaysdietitian.com/ newarchives/070112p32.shtml

Goodin, T. & Dillard, H. (In Press). Think this, do this: *Utilizing the problem-based learning mindset in professional learning communities at work.* Solution Tree Press.

Hennessy, M. (2019, July 16). *Chasing umami: the rise and rise of fermented food.* Food Navigator-USA.com. https://www.foodnavigator-usa.com/Article/2014/08/21/Packaged- Facts-on-growing-popularity-of-artisanal-fermented-food

Zemser, R. (2019, July 16). *Fermentation-an old process made new*. Natural Products Insider. https://www.naturalproductsinsider.com/regulatory/fermentationan-old-process-made- new

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Preparing Area Pipeline Students: Evaluation of a STEM Summer Engineering Bridge Program

Selvam B. Pillay, K. Madeline Boykin, Jeffrey W. Holmes, Haibin Ning, Krusha Patel, Mubenga N. Nkashama & Jonathan Bonner (University of Alabama at Birmingham)

Introduction The UAB Blazer Engineering Summer Bridge Program (BESB) was a four-week summer bridge program designed to ensure the advancement of incoming UAB School of Engineering (SOE) students considered at-risk due to deficits in math knowledge, critical and divergent thinking, and academic preparedness exacerbated by the effects of the COVID-19 Pandemic. The program was specifically designed to focus on the success of minority, women and firstgeneration college students from within the State of Alabama generally and especially from the greater Birmingham, Alabama area. Students in the program were engaged in engineering activities in three broad categories: Academic improvement in math, engineering science, English and academic advising; Professional development in time management, study skills, career development, and others; social development through networking, building community, and family support), and entrepreneurial opportunities in STEM.

Methodology and Research BESB was designed to provide early engagement and math preparation in at-risk students to foster a better start in students' academic careers as engineering majors by integrating engineering hands-on laboratory, research, and manufacturing activities, interactions with practicing engineers, daily math sessions, and technical writing workshops. The seed project funded by the Alabama Commission on Higher Education was considered by college leadership to be an investment in how summer bridge programs may improve student preparation and performance.

The program included novel pedagogical modules designed to promote awareness and problem-solving of environmental issues related to global climate change following Bybee's 5E model (Bybee et al., 2006; Bybee, 2014; Bybee 2009). Each module consisted of a multi-session overview to *engage* students and allow them to *explore* the concepts surrounding global climate change effects, outcomes, or solutions. The exploration session included a hands-on project kit for building or testing each particular concept or idea. After each experiment, the students were led to *explain, elaborate and evaluate* the activity for broader understanding. These modules were then coupled with sessions with "real-world" practicing engineers to discuss the application of science for resolution of engineering challenges.

The academic development program placed high emphasis on bolstering math skills necessary for college level math (NAEP, 2016; Crain, 2015). UAB's math placement test was used to develop a baseline and assess student readiness at the beginning of the program. Following this, students spent two hours daily in math tutoring sessions including ALEKS software for authentic problem solving and mathematical modeling in a progressive, adaptive-based learning environment. ALEKS allowed for implementing an adaptive pedagogical model starting with an assessment of basic competency and progressively strengthening weak areas for higher level understanding.

Data Analysis Student evaluations of the program included assessment of pre- and post-program ALEKS (Baker, 2016) testing to determine overall success of the math portion of the program, pre- and post-program Mathematics Attitude Inventory testing to measure student attitudes toward mathematics and science (Paciorek, 1997), and a novel self-assessment survey to examine overall attitudes students had of the program.

The post-program survey which was developed by the project PI (Pillay, 2023) with assistance from the project team consisted of 22 questions with Likert-scale responses to evaluation questions. Responses ranged from "strongly agree" to "strongly disagree" and keyed to specific portions of the program. Of particular interest the survey found that a large portion of respondents felt that time dedicated to math practice should be expanded, and the societal aspects of the program should be expanded. All agreed that the program was worthwhile. The results of these surveys are useful for planning and expanding similar future programs to strengthen the overall impact.

Outcomes Sixteen students took the math placement test during the BESB program. Students generally took the test (1) at the beginning of the program, (2) mid-way through the program (progress score); and (3) at the conclusion of the program. The scores showed the program had a positive impact on participant math skills. In some cases, students advanced two levels in math from pre-algebra to calculus.

Conclusions from the academic programming included the following: (1) Incoming freshmen engineering students may lack the necessary math and science critical thinking skills needed for a successful engineering career. Summer engineering bridge programs can be beneficial in exposing these students to such pathways necessary to advance in this field of study. (2) The UAB BESB was successful in reducing negative math anxiety by providing conceptual and actual problem-solving skills that might not have been taught in their high-school setting.

(3) The program was beneficial for student's learning opportunities in math and science, and the overall program was received positively by students and the UAB leadership team.

(4) Students generally provided favorable responses to the structure and content of the program based on preand post-test MSI results, as well as post-program survey results.

Social time and events provided additional conclusions supporting the importance of combining extra-curricular activities with academic programming. The societal setting, especially the college dormitory experience, allowed for the formation of a positive social network and the formation of social bonds that boosted the overall positive experience for the students and built a comradery where individuals were encouraged to excel by the group as a whole.

To improve data robustness, future iterations of the program should provide one-on-one exit interview for students to express their opinions on program positive and negative aspects and point-of-view changes that would make the program better. Future iterations of the program should include a Resident Assistant for those students who might not yet be 18 so they can benefit from the social interactions living in an on-campus dorm.

The UAB leadership team for the BESB project and the SOE administration believe the continuation of programming would address a critical need for bridging students into STEM fields. As the daily programming results from summer program were being assessed, the SOE leadership discussed with Arts and Science College leaders how UAB STEM could benefit from expanded student participation. Ongoing UAB leadership dialog with Birmingham area school systems is working to explore how a bridge program may be an effective way to increase student success. The program opportunity to develop outcomes provided by the Alabama Commission on Higher Education is appreciated.

References (Literature Review)

Baker, H., ALEKS User Guide for Higher Education Mathematics, ALEKS Corporation, McGraw Hill, 2016.

Bybee, Rodger W., et al. "The BSCS 5E instructional model: Origins and effectiveness." Colorado Springs, Co: BSCS 5.88-98 (2006).

Bybee, R., The BSCS 5E instructional model: Personal reflections and contemporary implications, Science and Children 51.8; 10-13, 2014.

Bybee, R., The BSCS 5E instructional model and 21st century skills, Colorado Springs, CO: BSCS 24, 2009.

Paciorek, E., Mathematics and Science Attitude Inventory [Measurement instrument]. Rochester Institute of Technology "Project EDGE," Retrieved from https://oerl.sri.com/instruments/up/studsurv/instr129.html, 1997.

Pillay, B., Student Survey of Program Elements, University of Alabama at Birmingham, 2023.

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Psychometrics of a Researcher-made Worked Examples Assessment for Math Word Problem Solving

Vishakha Agrawal, Anna H. Miller, Hailey Kepiro, Marcia A. Barnes (Vanderbilt University) & Sarah Powell (University of Texas at Austin)

Introduction Elementary school word problems tend to fall into three main problem types, often referred to as "schemas" (i.e., change, compare, and combine). Explicit instruction in the three problem types has been shown to be effective for improving problem solving in students, especially students with and at-risk for math learning disabilities and deficits in word problem solving (Powell, 2011). Word problem solving in elementary school is a complex cognitive process and involves reading, arithmetic fluency, and algebraic thinking.

Cognitive load refers to an individual's working memory capacity when performing tasks. Cognitive Load Theory suggests that novice learners benefit when learning is decoupled from problem solving, thereby lowering the students' cognitive load during learning and allowing them to focus more on acquiring and assimilating knowledge (Renkl & Atkinson, 2010). Worked problems show the problem set-up and the solution, which eliminates the need for problem solving while learning.

Worked problems are a commonly used instructional tool in mathematics for skills such as operations and arithmetic. Mathematics-related research on worked problems focuses on interventions incorporating worked problems with older students and those not identified with math learning disability (Barbieri et al., 2023). Limited studies examine worked example assessments especially for word problem solving and their reliability and validity with young students with MD. Having a psychometrically sound worked examples measure can allow us to examine how young students with MD approach worked word problems (e.g., can they accurately identify whether the worked problem is correct or not). Understanding student approaches to worked problems, especially for complex skills like math word problem solving, can help improve instruction that incorporates worked problems.

Research Questions 1. What is the test-retest reliability for a researcher-made worked word problem measure for 3rd grade students with MD? 2. Is the researcher-made worked word problem measure a valid measure of word problem solving skill?

Methods 154 3rd grade students with MD were shown nine worked word problems (three total, three difference and three change schema problems) at both pre- and post-test. Students were randomized to receive either word problem solving intervention or business as usual. Within each of the three schema types (i.e., change, compare, combine), one problem was correctly set up and the arithmetic was done correctly, one problem was set up incorrectly but used correct arithmetic, and one problem was set up correctly but had arithmetic errors. Students were shown each problem one at a time and asked to identify if the problem was correct or incorrect. After students gave an answer, examiners continued asking scripted questions to explore student thinking about each problem. Analyses provided here use data from the first question, "is the work correct or incorrect?"

Data Analysis Plan The current analyses examine response accuracy across the nine worked problems at both pre- and post-test. If a student was able to correctly identify if a worked example was correct (i.e., all parts of the problem were set up correctly) or incorrect (i.e., some part of the problem is wrong), we consider that to be an accurate response. To assess test-retest reliability, we use the "psych" package in R to calculate the intraclass correlation between the pre- and post-test timepoints of the worked examples assessment. To assess validity of the measure, we report the Pearson's correlation of the worked examples measure with established measures of mathematical achievement taken at the same time-point in the same sample.

Results Preliminary findings suggest that at both pre- and post-test young students with MD are better at detecting incorrect arithmetic than identifying schema-based errors (i.e., if a word problem is set up incorrectly). Students are more likely to provide correct responses to change problems that use vocabulary involving money (e.g., earn or loss), and can identify when these problems are set up incorrectly more frequently than other schema types. Additional analyses for test-retest reliability and validity are being conducted, and differences between pre- and post-test performance will be described.

Discussion Our findings suggest that third-grade students with and at-risk for math word problem solving difficulties rely on arithmetic clues to decide whether a worked problem is correct. Students may have trouble identifying if a worked problem is set up correctly based on a given word problem. Based on the pre-test and post-test findings we make recommendations for the design of worked problem assessments for young children with MD.

References

Barbieri, C. A., Miller-Cotto, D., Clerjuste, S. N., & Chawla, K. (2023). A meta-analysis of the worked examples effect on mathematics performance. *Educational Psychology Review*, *35*(1), 11.

Powell, S. R. (2011). Solving word problems using schemas: A review of the literature. *Learning Disabilities Research & Practice, 26*(2), 94-108.

Powell, S. R., Berry, K. A., Fall, A. M., Roberts, G., Fuchs, L. S., & Barnes, M. A. (2021). Alternative paths to improved word-problem performance: An advantage for embedding prealgebraic reasoning instruction within word-problem intervention. *Journal of Educational Psychology*, *113*(5), 898.

Renkl, A., & Atkinson, R. K. (2010). Learning from worked-out examples and problem solving. In J. L. Plass, R. Moreno, & R. Brünken (Eds.), C*ognitive load theory (*pp. 91- 108). Cambridge University Press. ttps://doi.org/10.1017/CBO9780511844744.007

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The Impact of Two Sequential CURES on Student Outcomes in an Introductory Biology Laboratory Course

Authors *Emma Throneburg, Rachel Pigg, PhD, Natalie Christian, PhD, Jeffery Masters, PhD, and Mikus Abolins-Abols, PhD Abstract*

Abstract Course Based Undergraduate Research Experiences (CUREs) allow students to participate in authentic research within their undergraduate courses. This enables a broader population of students to experience the benefits that authentic research experiences provide. CUREs that are incorporated into introductory courses further increase accessibility to more students, and potentially increase retention by supporting things such as scientific literacy, self-efficacy, science identity, as well as sense of belonging.

At the University of Louisville, a two-semester CURE that incorporates both molecular biology and ecology is built into introductory biology laboratory courses for STEM majors. This CURE was first implemented in the fall of 2021. Students completed surveys assessing their concept mastery, attitudes, and demographics. Survey data is collected three times throughout the duration of the two-semester CURE: at the beginning of the first semester, the end of the first semester, and the end of the second semester. Preliminary analyses of survey results will be presented.

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U.S. Mathematics Major Retention and Attrition: A Survey Study

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Abstract In today's quickly evolving world, there is a pressing need for more students with science, technology, engineering, and mathematics (STEM) degrees (PCAST, 2012). Those who earn degrees in mathematics, especially, offer a substantial contribution to technology, national security, and climate study. They can also pursue research-based careers and contribute knowledge to both applied and pure mathematics. However, an overwhelming 52% of declared mathematics majors nationwide change their major in the course of their college career (Leu, 2017). Moreover, students from underrepresented groups in mathematics, such as women, leave the field at higher rates during college (Lacampagne et al., 2007; Piatek-Jimenez, 2015). In efforts to better understand retention and attrition in the mathematics major, we pose the research question, what reasons do students report for choosing to stay in and leave the mathematics major?

This project is currently in the survey development phase, so the remainder of this abstract outlines the background literature, our anticipated data collection and analysis strategy, how we anticipate presenting our results at SSERC in the form of a poster in January 2024, and the potential implications for answering our research question.

Background Among research of STEM majors broadly, studies have indicated STEM attrition may be tied to race and/or gender (e.g., Belser et al., 2018; Chen & Soldner, 2013; Cundiff et al., 2013; Gayles & Ampaw, 2014), instructional methods and quality of instruction experienced in STEM courses (e.g., Ellis et al., 2016; Watkins & Mazur, 2013), and advanced courses taken pre-college (e.g., Rask, 2010). There have been large, nationwide, quantitative studies conducted concerning students in STEM majors to determine factors related with STEM persistence and attrition, but the majority of these studies have included mathematics majors in a broader category of STEM rather than investigate student attrition specific to the mathematics major (e.g., Beasley & Fischer, 2012; Daempfle, 2003; McDade, 1988). We assert there is a need to investigate reasons students leave the mathematics major specifically because students in each STEM discipline encounter unique challenges which would not be identified as reasons for attrition in STEM more broadly. For example, mathematics students may struggle with their mathematical identities and self-efficacy as they transition from computational mathematics courses, to more abstract and theoretical proof-based mathematics courses (Civian & Schley, 1996).

In efforts to investigate retention and attrition specific to the different STEM disciplines, Rask (2010) separated data by intended student major in order to detect differences in retention trends among the different STEM majors, but the data were composed of student grades and courses taken rather than qualitative responses regarding why students chose to leave. Similarly, Rasmussen and Ellis (2013) investigated students who chose to leave or stay in STEM after calculus I, but all data in this study were also quantitative. Although these data apply to mathematics majors, retention of students desiring to study mathematics specifically was not addressed. The results from these studies indicate women are switching out of mathematics at higher rates than men, STEM courses have grade distributions lower than the college average, and students are choosing to suspend their mathematical studies because they have changed to a non-STEM major. Although quantitative data may allow researchers to find patterns and speculate why students chose to leave their major, we look to qualitative studies in efforts to identify the circumstances and reasons for students changing out of the mathematics major.

Internationally, there have been efforts to more deeply research the experiences of mathematics majors through qualitative interviews and case studies (e.g., Hall et al., 2022; Rodd & Bartholomew, 2006; Ward-Penny et al., 2011). Results from these studies, based in the United Kingdom (Rodd & Bartholomew, 2006; Ward-Penny et al., 2011) and Australia (Hall et al., 2022) have suggested students become disaffected with their mathematics major. Many chose to major in mathematics because it was easy for them in secondary school, but it is now a challenge at university. Others described their dislike for lecture-based instruction and feeling as though their courses place a strong emphasis on memorization. Although these international qualitative studies may provide insight into the mathematics major experience in the United States, there are differences in culture and schooling systems between the United States and other parts of the world which require an investigation specific to undergraduate mathematics in the US.

Methods During Fall 2023, we are carrying out a nationwide survey with free-response items of students who have been enrolled in a mathematics major at four-year institutions. In addition to general demographic information (race, gender, age, etc.), this survey solicits information such as: reasons for enrolling in a mathematics major, mathematics courses taken at the university level, type of institution attended, instructional methods experienced in university mathematics courses, and timing of and reasons for deciding to either leave or stay in the mathematics major. Data will be collected in October 2023 and data analysis will begin in November 2023.

To analyze the survey responses, we will separate data by responses from students who have left, enthusiastically stayed, and reluctantly stayed in the mathematics major then inductively analyze free-response survey responses of leavers to identify themes among student-reported reasons for leaving as well as inductively analyze the responses of students who stayed in the mathematics major to identify themes to describe the supports, circumstances, and other reasons for remaining in the mathematics major. Further, we will compare the student-reported reasons for leaving and staying in the mathematics major to the courses taken and instructional methods experienced as well as the students' reported reasons for initially choosing to major in mathematics.

Presentation of Findings and Potential Implications This survey project is funded through [Funding Source Redacted for Blind Submission] and is to be conducted during the Fall 2023 semester. In our 2024 SSERC poster, we will report on several elements of the survey responses, including: the total number of survey responses, demographic description of survey participants, themes developed through our inductive analysis of free-response survey items for both students who left and stayed in the mathematics major, and most prevalent reported reasons for leaving and staying compared to information such as institution type, participant identities, and/or timing of decision to change majors.

Results from our study will characterize the reasons undergraduate students report for choosing to major in mathematics as well as their reasons for either leaving or staying in the mathematics major. Although this research will produce a framework for future researchers to use when continuing research on retention in the mathematics major, the research findings will further inform instruction and administration across K-16 mathematics. By both addressing the reasons students report for leaving mathematics and capitalizing on student reported reasons for staying in mathematics, we anticipate our findings will inform how to better prepare K-12 students for choosing a college major, support students with a desire to major in mathematics in their transition to university level mathematics, illuminate instructional strategies that promote retention in university mathematics courses, and identify critical points in undergraduate mathematics education in which mathematics majors could benefit from additional guidance and support.

References

Beasley, M. A., & Fischer, M. J. (2012). Why they leave: The impact of stereotype threat on the attrition of women and minorities from science, math and engineering majors. *Social Psychology of Education*, *15*(4), 427–448. https://doi.org/10.1007/s11218-012-9185-3

Belser, C. T., Shillingford, M. A., Daire, A. P., Prescod, D. J., & Dagley, M. A. (2018). Factors influencing undergraduate student retention in STEM majors: Career development, math ability, and demographics. *The Professional Counselor*, *8*(3), 262–276. https://doi.org/10.15241/ctb.8.3.262

Chen, X., & Soldner, M. (2013). *STEM attrition: College students' paths into and out of STEM fields (NCES 2014-001)*. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Civian, J., & Schley, S. (1996). Pathways for women in the sciences II: Retention in math and science at the college level. *Annual Meeting of the Americal Educational Research Association*.

Cundiff, J., Vescio, T., Loken, E., & Lo, L. (2013). Do gender–science stereotypes predict science identification and science career aspirations among undergraduate science majors? *Social Psychology of Education*, *16*. https://doi.org/10.1007/s11218-013-9232-8

Daempfle, P. A. (2003). An analysis of the high attrition rates among first year college science, math, and engineering majors. *Journal of College Student Retention: Research, Theory & Practice*, *5*(1), 37–52. https://doi.org/10.2190/DWQT-TYA4-T20W-RCWH

Ellis, J., Fosdick, B. K., & Rasmussen, C. (2016). Women 1.5 times more likely to leave STEM pipeline after calculus compared to men: Lack of mathematical confidence a potential culprit. *PLoS ONE*, *11*(7). https://doi.org/10.1371/journal.pone.0157447

Gayles, J. G., & Ampaw, F. (2014). The Impact of College Experiences on Degree Completion in STEM Fields at Four-Year Institutions: Does Gender Matter? *The Journal of Higher Education*, *85*(4), 439–468. https://doi.org/10.1080/00221546.2014.11777336

Hall, J., Robinson, T., Flegg, J., & Wilkinson, J. (2022). First-year and final-year undergraduate students' perceptions of university mathematics departments. *Mathematics Education Research Journal*, *34*(2), 189–214. https://doi.org/10.1007/s13394-020-00340-z

Lacampagne, C. B., Campbell, P. B., Herzig, A. H., Damarin, S., & Vogt, C. M. (2007). Gender equity in mathematics. *Handbook for Achieving Gender Equity through Education*, *2*, 235–254.

Leu, K. (2017). *Beginning college students who change their majors within 3 years of enrollment* (NCES 2018-434; Data Point). National Center for Education Statistics. https://files.eric.ed.gov/fulltext/ED578434.pdf

McDade, L. A. (1988). Knowing the "right stuff": Attrition, gender, and scientific literacy. *Anthropology & Education Quarterly*, *19*(2), 93–114.

Piatek-Jimenez, K. (2015). On the persistence and attrition of women in mathematics. *Journal of Humanistic Mathematics*, *5*(1), 3–54. https://doi.org/10.5642/jhummath.201501.03

President's Council on Advisors on Science and Technology (PCAST). (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*.https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to- excel-final_2-25-12.pdf

Rask, K. (2010). Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Economics of Education Review*, *29*(6), 892–900. https://doi.org/10.1016/j.econedurev.2010.06.013

Rasmussen, C., & Ellis, A. B. (2013). Who is switching out of calculus and why. In A. M. Lindmeir & A. Heinze (Eds.), *Proceedings of the 37th Conference for the International Group for the Psychology of Mathematics Education*.

Rodd, M., & Bartholomew, H. (2006). Invisible and special: Young women's experiences as undergraduate mathematics students. *Gender and Education*, *18*(1), 35–50.

https://doi.org/10.1080/09540250500195093

Ward-Penny, R., Johnston-Wilder, S., & Lee, C. (2011). Exit interviews: Undergraduates who leave mathematics behind. *For the Learning of Mathematics*, *31*(2), 21–26.

Watkins, J., & Mazur, E. (2013). Retaining students in science, technology, engineering, and mathematics (STEM) majors. *Journal of College Science Teaching*, *42*(5), 36–41.

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Use of Smartphone Sensors to Enhance Lab Activities in an Introductory Physics Course

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Abstract Modern smartphones incorporate a wide array of accurate sensors that can be used for scientific experiments in the classroom. At the Air Force Academy, we have been attempting to introduce students to these capabilities and inspire an appreciation for how these devices can help students understand the physical world. We created interactive laboratory activities exploiting smartphone sensor data to reinforce the physics concepts we are covering in our Scholars Physics I course. The primary app we have utilized is the PhyPhox application, created at the Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen University. This user-friendly app allowed students to collect and analyze data from a series of experiments conducted in class. Students discovered the power of the device they carry daily to explore acceleration due to gravity, the relationship between angular velocity and centripetal acceleration, and simple harmonic motion. The app allows students to view plots as data are being collected. They can extract average values directly from their phone or export the raw data to a computer in various formats for more in-depth analysis.

This poster will present our lessons learned during a year of implementation and share ideas about how to incorporate smartphone-collected data in classroom activities. Our students responded positively to the way a smartphone app can plot data as it is being collected, reinforcing how a graph represents motion. Smartphone use streamlines data collection and plotting, but the activities are similar to traditional labs. The main difference is that students are able to perform more trials in less time, accelerating learning. Assessment of understanding was based on reviewing student responses on lab worksheets. Incorporating these activities in the classroom only required students to download a free app to their smartphone. Depending on the experiment, some instruction may be necessary to guide students to understand what the smartphone sensors are measuring, and how to export data to a computer for additional analysis. We experienced no significant challenges related to using this tool in classroom activities. Several similar apps are available at no cost, and students are typically interested in investigating new ways to utilize their mobile devices to explore the concepts introduced in a physics course. The feedback from the first year incorporating this tool in classroom activities has been very positive.

Background Literature

Staacks, Sebastian, et al. "Advanced tools for smartphone-based experiments: phyphox." *Physics education* 53.4 (2018): 045009.

Ars Legendi-faculty Award for development of the PhyPhox app and its effect on physics education: https://www.stifterverband.org/ars-legendi-mn

PhyPhox Website describing numerous classroom activities and applications: https://phyphox.org/st

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