S²ERC

SOUTHEASTERN STEM EDUCATION RESEARCH CONFERENCE

2023

JANUARY 13-14, 2023

HOSTED BY

TENNESSEE TECH UNIVERSITY

COOKEVILLE, TENNESSEE

17th Annual Tennessee STEM Education Research Conference
January 13-14, 2023

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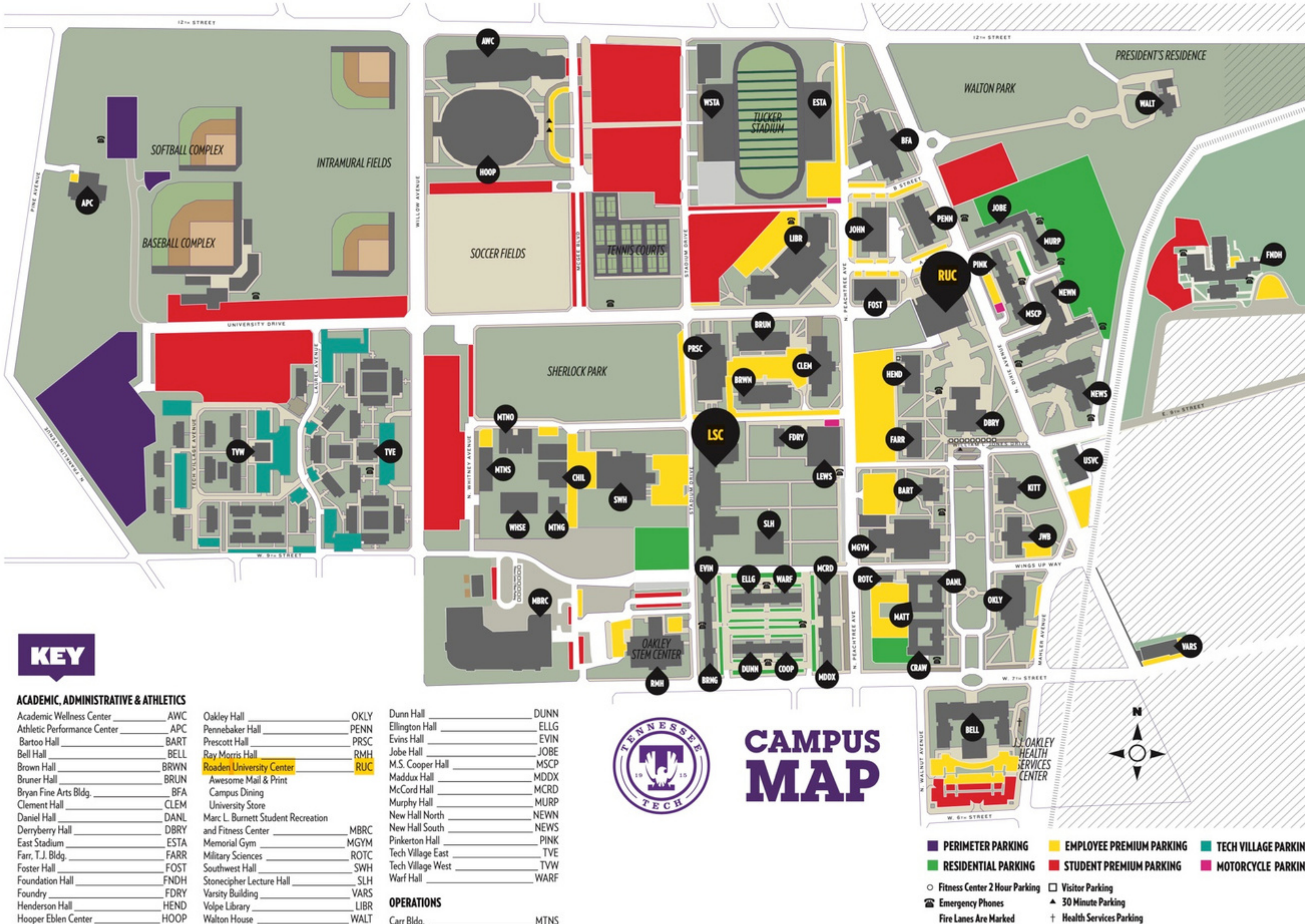

PARKING INSTRUCTIONS

FRIDAY (RUC):

BEFORE 4:30 PM - RED OR PURPLE LOTS

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EVENT SCHEDULE

POSTER SESSIONS SPONSORED BY

COLLEGE OF BASIC AND APPLIED SCIENCES

MIDDLE TENNESSEE STATE UNIVERSITY

17th Annual Southeastern STEM Education Research Conference
January 13-14, 2023

January 13, 2023

12:00pm Registration Opens – Roaden University Center 282

12:00pm – 4:00pm Poster Session Setup – Roaden University Center 282

1:00pm – 2:30pm Early Career Panel – Roaden University Center 101

1:30pm – 3:30pm Refreshments – Roaden University Center 282

2:45pm – 3:45pm Session 1

Math Education – TJ Farr 106 (Facilitator – Kingsley Adamoah)

- **Building mathematics teachers' pedagogical design capacity**, Sarah Hartman, Nicholas Fortune, and Hope Marchionda (Western Kentucky University)
- **Instructor perceptions of student example use**, Jordan Kirby (Middle Tennessee State University)

STEM Education - Roaden University Center 101 (Facilitator – Heather Bertram)

- **Measuring learner behavior using wearable AR**, Isaac Shirk, John Wallin, Michael Hein, Andrienne Friedli, Rafet Al-Tobasei, Michael Sharp, and Austin Fine (Middle Tennessee State University)
- **Promoting STEM education in higher education through an interdisciplinary approach for early childhood education students**, Seok Jeng Jane Lim and Karen Reed (Middle Tennessee State University)

STEM Education - Roaden University Center 282 (Facilitator – Carey Wilson)

- **A community of practice for STEM education graduate students: Lunch and learn**, Tim Ransom, Jessica Manning, and Randi Sims (Clemson University)
- **A quantitative analysis on the effects of COVID-19 in associate programs versus bachelor programs using initial written exam scores for aircraft mechanics**, Collin McDonald (Middle Tennessee State University)

4:00–6:00pm Poster Session – Roaden University Center 282

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

1. **A new survey of perceived conflict between evolution and religion reveals differences in atheist and Christian biology students' perceived conflict between religion and evolution,** Katie Coscia (Middle Tennessee State University), Sara Brownell (Arizona State University), and Elizabeth Barnes (Middle Tennessee State University)
2. **An experimental study testing the effect of biology instructor identity on reducing students' perceived conflict between evolution and religion**, Rahmi Aini, Alexa Summersill, Casey Epting (Middle Tennessee State University), Sara Brownell (Arizona State University), and Elizabeth Barnes (Middle Tennessee State University)

Poster Session – Roaden University Center 282 (continued)

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

3. **Undergraduate biology students show patterns of identity protective cognition and motivated reasoning about evolution**, Madison Stewart, Elizabeth Barnes (Middle Tennessee State University), and Sara Brownell (Arizona State University)
4. **Assessing validity and reliability evidence of a general chemistry assessment,** Taylor Humphreys, Casandra Koevoets-Beach, and Morgan Balabanoff (University of Louisville)
5. **Exploring retrieval difficulties and self-confidence in the assessment of general chemistry students**, Karen Julian, Casandra Koevoets-Beach, and Morgan Balabanoff (University of Louisville)
6. **Exploring students' epistemological understanding of atomic structure models**, Claire Ward and Morgan Balabanoff (University of Louisville)
7. **Measuring response confidence: Exploring an affective construct within a general chemistry assessment,** Casandra Koevoets-Beach, Morgan Balabanoff, Karen Julian, and Taylor Humphreys (University of Louisville)
8. **Student discourse networks and group composition in a POGIL-based general chemistry class**, Karolin Abouelyamin, Sylvia Zakher(Middle Tennessee State University), Joshua Reid (Texas Tech University), and Gregory T. Rushton (Middle Tennessee State University)
9. **Exploring how empathy education changes students' perceptions of an "engineer"**, Libby Flanagan and Karen High (Clemson University)
10. **Order matters for creating 3D representations**, Jill Cochran, Cody Gordon, Sabrina Bagley, Zane Cochran, and Hannah Zemke (Berry College)
11. **Learning astronomy with the use of wearable augmented reality**, Michael Hein, John Wallin, Andrienne Friedli, Brenna Armfield, Ayat Tamimi, and Isaac Shirk (Middle Tennessee State University)
12. **CyberLearnAR: The development of a wearable augmented reality system for teaching STEM**, John Wallin, Isaac Shirk, Rafet Al-Tobasei, Andrienne Friedli, Michael Sharp, Nico Kaszynski, AustinFine, and Michael Hein (Middle Tennessee State University)
13. **Describing how teacher questioning elicits student thinking in an interdisciplinary STEM lesson**, Lori Klukowski,Seth Jones, Fonya Scott, and Sara Salisbury (Middle Tennessee State University)
14. **Digital agriculture summer camp: an examination of non-formal learning to promote knowledge and postsecondary STEM interests**, Carly Altman and Chaney Mosley (Middle Tennessee State University)
15. **Digital storytelling reimagined: a framework for data literacy and interdisciplinary learning in K-12 classrooms**, Tisha Brown-Gaines, Mary Ellen Pethel, Heather Finch, and Emmanuel Saka (Belmont University)
16. **Identifying USAFA majors susceptible to STEM attrition through major flow analysis**, Wilson Gonzalez-Espada (Morehead State University), Daniel S. O'Keefe and David Meier (United States Air Force Academy)
17. **Initial impacts of a STEM professional learning institute for preschool educators**, Alissa Lange and Amie Craven (East Tennessee State University)
18. **Learn by teaching: learning biomedical informatics topics through intern-generated media,** Robert Becker, Michelle Gomez, and Kim M. Unertl (Vanderbilt University)

6:00–8:00pm Dinner and Keynote Presentation – Roaden University Center 282

- Keynote Speaker - Dr. Tessa Andrews, University of Georgia
  "Making the most of active learning: The role of teaching expertise"

January 14, 2023

7:30am Registration Opens – Lab Science Commons Lobby

8:00am – 9:00am Breakfast – Lab Science Commons Lobby

9:00am – 10:30am Session 2
Biology Education - Lab Science Commons 1201 (Facilitator - Lori Klukowski)

- **Biological thinking: A comparison between majors' and non-majors' mindsets**, Kendra Wright and Jaime Sabel (University of Memphis)
- **Engagement in metacognition among undergraduate biology students**, Alixandria Kirkendol and Jaime Sabel (University of Memphis)
- **Investigating undergraduate students' engagement in systems thinking using causal maps**, Sedra Sous and Jaime Sabel (University of Memphis)

Science Education - Lab Science Commons 1205 (Facilitator – Brandon Vandergriff)

- **A curriculum analysis of how students work with data in open Sci Ed and CK-12 units**, Amanda Garner and Joshua Rosenberg (The University of Tennessee, Knoxville)
- **Data analysis in science classrooms: Teachers' perspective**, Omiya Sultana, Joshua Rosenberg (The University of Tennessee, Knoxville), Elizabeth H. Schultheis, Melissa K. Kjelvik (Michigan State University), and Aaron Reedy (Data Classroom)

STEM Education - Lab Science Commons 1211 (Facilitator – Fonya Scott)

- **Who am I?**, Lisa Salvato (Tennessee Technological University)
- **The navigation of STEM and racial identities within marginalized graduate students and the influence of research mentors**, Kathryn Hosbein (Middle Tennessee State University), Paulette Vincent-Ruz (New Mexico State University), Madison Gillis and Wanqi Feng (University of Michigan)
- **You gotta work, BASIL! Reimagining an established CURE to provide high-quality digital learning experiences that are intentionally equitable, inclusive, and accessible for all students**, Arthur Sikora (Nova Southeastern University)

10:30am–10:45am Break

10:45am– 12:15pm Session 3

Math Education - Lab Science Commons 1201 (Facilitator – Samantha Fletcher)

- **Prospective secondary mathematics teachers' expectancy and value for enacting core teaching practices**, Kingsley Adamoah, Christopher Bonnesen, and Jeremy Strayer (Middle Tennessee State University)
- **The influence of social interactions on student mathematical creativity in the high school classroom**, Meghan Riling (Vanderbilt University)
- **Will I ever use this? Closing equity gaps in math with utility-value interventions**, Chris Hulleman, Yoi Tibbetts, Michelle Francis, Alison Lubin, Delaram Totonchi (University of Virginia), Kenn Barron (James Madison University), and LaDonna Young (Motivate Lab)

Science Education - Lab Science Commons 1205 (Facilitator – Rosina Andrews)

- **The trajectory of science teachers after the leadership program**, Andrea Reeder and Gregory T. Rushton (Middle Tennessee State University)
- **Implementation of the EOP model guided by the Renaissance Foundry Model**, Pedro Arce (Tennessee Tech University), Andrea Arce-Trigatti (Tallahassee Community College), and Dipendra Wagle (Tennessee Technological University)

STEM Education - Lab Science Commons 1211 (Facilitator – Julia Grecol)

- **Computational thinking: Engaging students in STEM in the post-pandemic era**, Tisha Gaines (Belmont University)
- **Informal STEM event impacts on preservice teacher volunteers and families**, Nyasha Dzenga, Shawn Hinkel, Carey Wilson, Jennifer Meadows, and Jane Baker (Tennessee Technological University)
- **Strength- and weakness-based reflection among STEM faculty**, Amanda Lake Heath, Sarah K. Bleiler-Baxter, Fonya C. Scott, O. Theresa Ayangbola (Middle Tennessee State University), Olena T. James (Belmont University), Gregory T. Rushton and Grant E. Gardner (Middle Tennessee State University)

12:15pm–1:30pm Lunch – Lab Science Commons Lobby

1:30pm– 3:00pm Session 4

Biology Education - Lab Science Commons 1205 (Facilitator – Katie Coscia)

- **Patterns for managing potential conflict between religion and evolution among Muslim undergraduate biology students**, Rahmi Qurota Aini (Middle Tennessee State University), Sara Brownell (Arizona State University), and Elizabeth Barnes (Middle Tennessee State University)
- **Undergraduate science communication about culturally controversial science topics: The role of politics, religion, and race**, Elizabeth Barnes (Middle Tennessee State University)

1:30pm– 3:00pm Session 4 (continued)
STEM Education - Lab Science Commons 1211 (Facilitator – Andrea Reeder)

- **Elevating student voices to catalyze system change in STEM education**, Yoi Tibbetts and Chris Hulleman (University of Virginia)
- **Faculty reflections on inclusive pedagogy within STEM classrooms**, O. Theresa Ayangbola, Fonya C. Scott, Sarah K. Bleiler-Baxter (Middle Tennessee State University), Olena T. James (Belmont University), Amanda Lake Heath, Grant E. Gardner, and Gregory T. Rushton (Middle Tennessee State University)

EARLY CAREER PANEL

FRIDAY, JANUARY 13TH, 2023
1:00PM-2:30PM
ROADEN UNIVERSITY CENTER (RUC) 101

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EARLY CAREER PANEL

We are excited to kick off SSERC 2023 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

Dr. BRENNA TUCKER

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CHEMISTRY

Dr. OLENA JAMES

BELMONT UNIVERSITY
BIOLOGY

JOSH FORAKIS

UNIVERSITY OF ALABAMA AT BIRMINGHAM
CHEMISTRY

AMIE CRAVEN

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AMANDA LAKE HEATH

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MATHEMATICS

KEYNOTE SPEAKER

DR. TESSA ANDREWS

UNIVERSITY OF GEORGIA

FRIDAY, JANUARY 13TH, 2023
6:00PM-8:00PM
ROADEN UNIVERSITY CENTER (RUC) 282

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Mathematics and Science Education
Doctor of Philosophy Program

Keynote Speaker

Dr. Tessa Andrews
Department of Genetics
University of Georgia

Making the most of active learning: The role of teaching expertise

Dr. Andrews' interactive address will focus on the specialized teaching knowledge that faculty use to plan and carry out active-learning instruction in large classes. Though active-learning instruction can be highly effective at supporting student learning and reducing opportunity gaps, the results instructors achieve vary considerably. Dr. Andrews will present results from a series of published papers and ongoing research. These results reveal teaching knowledge that facilitates effective active-learning instruction and teaching knowledge that may limit the impact of active learning on students.

Tessa Andrews, PhD, is an Associate Professor of Genetics at the University of Georgia. She specializes in biology education research and aims for her research to inform and support the effective and widespread implementation of evidence-based teaching strategies in undergraduate STEM classrooms. Dr. Andrews studies faculty and the specialized teaching knowledge they use to plan and carry out evidence-based teaching. She also studies the systems in which faculty work, such as departments and institutions, and how these systems can be reformed to better encourage, incentivize, and reward evidence-based teaching. Dr. Andrews' work has been funded by multiple grants from the National Science Foundation, including a CAREER award. Her contributions as a teacher have been recognized by awards from the Morehead Honors College, University of Georgia, and the University System of Georgia. Dr. Andrews is a Monitoring Editor for CBE-Life Sciences Education and a Working Group Leader for the Accelerating Systemic Change Network. She earned a BS in Psychology, a PhD in Biological Sciences, and a Certificate of College Teaching from Montana State University.

ORAL PRESENTATIONS

AUTHORS AND ABSTRACTS

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SOUTHEASTERN STEM EDUCATION RESEARCH CONFERENCE

2023

Building mathematics teachers' pedagogical design capacity

Sarah Hartman, Nicholas Fortune, and Hope Marchionda (Western Kentucky University)

Research has shown that teaching is the most important school-based factor that impacts student success (Center for Education Policy Research, n.d.). We argue, and research corroborates, that effective instruction and high expectations are, in part, dependent upon the curriculum being used but are more importantly dependent on implementing curriculum with fidelity and with practices that align with research-based suggestions. Unfortunately, despite using rigorous mathematics curricula, many regional teachers feel their curriculum is not enough as many students are still underperforming despite being pulled for intervention. As such, these teachers are often utilizing the internet (e.g., Pinterest, Teachers-Pay-Teachers, and teacher blogs) as a source for supplemental resources to help meet the diverse needs of their students (Hunter & Hall, 2018). Research has shown that many teachers do not know how to determine whether or not these additional resources are appropriate in regard to content and research-based expectations for instruction (Peterson et al., 2019). This is not surprising as many teachers are not skilled in designing curriculum. That is, teachers are often lacking the pedagogical design capacity (PDC) (Brown & Edelson, 2003) needed to know how best to implement and refine these additional resources in a way that supports the learning goals for their classroom.

PDC is not necessarily a component built in teachers' educational training or in professional development (PD). However, given teachers' breadth and wealth of knowledge, we believe that developing teachers' PDC through carefully designed PD opportunities will be a beneficial endeavor. This opportunity can leverage teachers' current understandings and knowledge and develop their abilities as it relates to PDC for mathematics teaching. Additionally, it will engage teachers in what Farmer et al. (2003) call an inquiry stance toward teaching which research has linked to sustained teacher learning and improved student performance (Zehetmeier & Krainer, 2011).

Given the popularity and pervasiveness of free curricula resources combined with teachers underdeveloped PDC, there is an immediate and critical problem that needs to be addressed. This study is part of a larger study aimed to address this critical need. For the present study, we conducted a week-long professional development (PD), details below. Our research question is How does this professional development model develop teachers' PDC for mathematics teaching? More specifically, how does developing teachers' skills and knowledge for an inquiry stance toward teaching develop their PDC for mathematics teaching?

Brief Background Literature, PD Model, and Context

In 2019, Kentucky's Department of Education published characteristics of highly effective teaching and learning (Center for Education Policy Research, n.d.). The five characteristics that were identified are learning climate, classroom assessment and reflection, instructional rigor and student engagement, instructional relevance, and knowledge of content. The design of this PD and research focuses on developing teacher skills in each area in the context of PDC.

To design and facilitate effective mathematics instruction, teachers need to possess the pedagogical content knowledge (Shulman, 1986) that is needed in order to choose appropriate tasks that have high cognitive demand, to facilitate these tasks so that the level of domain remains high, and to analyze student thinking during and after the task. The goal of our professional development is to aid in participants' ability to identify strengths and weaknesses in teachers' current teaching practice and curriculum, collaborate with other teachers to create revised lesson plans that focus on school-specific curriculum, and learn to implement lessons in ways that align with research-based teaching practices. Additionally, the PD worked to create an environment where time was devoted to working directly with teachers design and implementation of their own curriculum and answer questions. We conducted a summer four-day PD with follow-up days in two subsequent semesters. Each day of the summer portion focused on a unique area of teaching and pedagogical design capacity: Identifying tasks as high and low level and analyzing them; analysis of localized resources (curriculum used within the school) to identify strengths and weaknesses of lessons within grade-band and improve each lesson collaboratively among teachers; norm setting in the classroom in conjunction with identification of student reasoning levels and building on student misconceptions in the classroom; and creating a modified lesson plan with material discussed in previous PD days. Throughout the school year, teachers implemented and videotaped their modified lesson plan in order to improve and reflect on their teaching. At PDs throughout the year, teachers reflected on peers' teaching and task implementation. We worked with 18 K-4 teachers from a local school district.

Methods

Recall our research question was: How does this professional development model develop teachers' PDC for mathematics teaching? More specifically, how does developing teachers' skills and knowledge for an inquiry stance toward teaching develop their PDC for mathematics teaching? To answer this question, we collected both qualitative and quantitative data. Qualitative data collected from teachers included their teacher-created lesson plans, video recordings of lesson implementation, daily reflections from teachers, and surveys on teachers' development of PDC. Quantitative data were collected but are not discussed in this proposal for space considerations. All qualitative data was uploaded into Atlas.ti. The research team read through and organized the data. In this initial reading we created memos to document initial thoughts. Then we utilized open coding to develop themes from the data (Creswell & Plano Clark, 2011). These open codes were based on literature or emerged from the data. We then met to discuss codes and look for reliability among the data and how it was being coded. Once this baseline was established, the rest of the data was coded. Disagreements were discussed and agreed upon. We then synthesized the findings and connected them back to the research questions.

Summary of Preliminary Findings

Given space we can only highlight a brief overview of the observed themes from the summer PD. A majority of teachers reported gaining knowledge regarding "MULTIPLE (sic) ways to implement discussions, strategies, questioning techniques, and wrong answers that produce higher level thinking in students," as well as valuing "being able to work with people from my school, being able to work with others who teach my grade, being in a 'safe environment' so that I could share ideas." At the beginning and end of the PD, we asked participants to define good mathematics pedagogy. After the PD experience, teachers defined good mathematics pedagogy as “engaging, student voiced, safe, and higher level in student thinking.”, “includes the process - right and wrong - of computation” and “being flexible and able to meet student needs by differentiation”. Additionally, we observed an increase in confidence levels in finding a high-level mathematics task or adapting a lower-level mathematics task so that it is high level (average of 6.6 out of 10 increased to 9.0 out of 10) as well as an increase in confidence levels regarding preparation to implement a high-level task in their classroom (average of 6.9 out of 10 increased to 8.9 out of 10). Survey data and qualitative analysis reveal this PD had a positive impact on self-reported teacher PDC. More analysis is ongoing of the video data from teachers’ lessons.

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Instructor perceptions of student example use

Jordan Kirby (Middle Tennessee State University)

I intend for this talk to be included in Ideas for Research Studies. Mathematics policy documents have pushed for proof and proving to be a more central educational goal at the K-16 level for mathematics students (National Governors Association (NGA)/ Council of Chief State School Officers, 2010; RAND Mathematics Study Panel, 2002). This emphasis on proof and proving has led researchers to further investigate how students come to understand the proving process. Researchers have commonly found students from K-16 struggle to understand the purpose of a proof and how to construct proofs (e.g., Harel & Sowder, 2007; Healy & Hoyles, 2000; Stylianides, 2007). One component leading to this struggle is the difficulty in understanding the purpose of examples in a proof context (Ellis et al., 2019; Epp, 2003; Aricha- Metzer & Zaslavsky, 2019).

Examples can aid both the production of proofs and comprehension when reading proofs for students (Epp, 2003; Selden & Selden, 2003). Many studies have investigated how students use examples in a proof context (e.g., Aricha-Metzer & Zaslavsky, 2019; Lockwood et al., 2016; Zaslavsky & Knuth, 2019). However, few studies in the field of example-use in proof investigate the mathematical knowledge for teaching that would support instructors of these proof classes to effectively build upon and communicate strategies of using examples to their students (Zaslavsky & Knuth, 2019). This study aims to answer this call to research presented from Zaslavsky and Knuth (2019) by investigating how instructors of introductory proof classes perceive their students to use examples to produce and comprehend proofs. To answer this call, I will answer the following research questions:

1. How do instructors of introductory proof classes perceive students' understanding and use of examples?
2. How do instructors of introductory proof courses respond to varied instances of student's use of examples?

This study is part of the author's dissertation. Instructors of introductory proof courses across the southeastern United States will be interviewed from September 2022 to November 2022. At the time of this conference, I expect to be done with data collection and midway through data analysis. During the interview, participants will be asked to respond to six student sample responses to two questions adapted from Balacheff (1987) regarding example-use in proofs. These responses will include feedback given to the students if they were in my participants classroom as well as tasks to move this student forward in their thinking. Later in the interview, the participants will sort and rank the six responses however they seem fit. These rankings may be based on how well the instructors perceive their students to be answering the question, or which responses the instructors think are the closest to a valid mathematical proof. These responses are expected to be focused on explanations regarding the understanding of students' example-use in proof described by Balacheff including naive empiricism, crucial experiment, and generic example.

The mathematical knowledge for teaching (MKT) framework outlined by Ball and colleagues (2008) will serve as an overarching analytical framework for this study. Mathematical knowledge for teaching describes both the pedagogical content knowledge (PCK) an instructor needs to teach mathematics, as well as the subject matter knowledge (SMK) to expertly teach the mathematics. This study looks to dive more deeply into subcategories of pedagogical content knowledge of instructors of introductory proof classes. In particular, the areas of knowledge of content and students (KCS—Research Question 1) and knowledge of content and teaching (KCT—Research Question 2) will be used to qualitatively code transcripts.

To use the MKT framework as an analytical tool, I will look for instances of KCS and KCT from the participants. Evidence of KCS may include ideas about expected student misconceptions, expected student understanding, and outcomes teachers hold in the classroom. Evidence of KCT may include how an instructor sequences problems in a course, how the instructor engages their students, and the steps instructors take to develop their students as learners of mathematics. These lenses will be used over the transcripts of this data to answer RQ 1 and RQ 2 respectively.

At the time of this conference, I expect to be in the middle of data analysis. One of the primary expected results is a categorization of how instructors of proof classes sort and rank the student responses. Instructors will further be asked to give responses to the students ranked highest and lowest in the sorting task. These responses will give insight into how instructors respond to students at varying levels of understanding example-use in introductory proof classes. I am seeking feedback from this proposal on my planned analysis methodology and coding scheme to ensure I answer the research questions given the data I will have available. This may include feedback on how the MKT framework can best be used as an analytical framework in my data. I would like to ask the audience at this conference if they believe the lens of KCS and KCT will be the best choices for data analysis. Finally, I am interested in feedback from this audience in discussion ideas to move this work forward.

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Measuring learner behavior using wearable AR

Isaac Shirk, John Wallin, Michael Hein, Andrienne Friedli, Rafet Al-Tobasei, Michael Sharp, and Austin Fine (Middle Tennessee State University)

AR is a technology that is characterized as combining the experience of 3D, virtual objects and physical objects in real time. The goal of the technology is to allow one to see and interact with things that one could not interact with normally (Azuma, 1997). Recent improvements in computing power, sensors, and displays have enabled the creation of wearable AR and a resurgence in excitement about the technology (Xiong Et al. 2021). These recent developments have kickstarted interest in using AR in the classroom as a means to enhance instruction (Petrov & Atanasova, 2020; Tashko & Elena, 2015). Because wearable AR is relatively new and evolving, there are few studies of its educational effectiveness in STEM classroom settings.

Although wearable AR is new, there have been studies investigating the use of AR in the classroom using mobile devices and screens. Most of these studies tend to rely on using tests covering the subject of a technology assisted lecture along with a questionnaire assessing participant's opinions of the technology and lecture experience (Petrov & Atanasova, 2020; Tashko & Elena, 2015). However, wearable AR technologies can also generate thousands of data points on how users are interacting with their virtual and physical environments that can also be used to gain insights about learning. The primary goal of this project was to integrate practices from Educational Data Mining (EDM) (Romero & Ventura, 2010) into our existing AR learning tool, CyberLearnAR. In addition to collecting pre and post tests and a questionnaire, we created tools to collect data on how students used and interacted with our AR application.

In this paper, we wish to address two questions:

1. What learner interactions can be automatically collected using wearable AR?
2. What measurements of engagement and behaviors can we derive from the collected data?

In a recent review, AR educational platforms were identified as a prime area for applying EDM (Romero & Ventura, 2020). This project will help demonstrate the wealth of data that can be collected and analyzed from an AR learning environment, as well as identify what data to collect and how it can be analyzed. While there are some papers combining AR projects with EDM techniques, there are no projects using wearable AR.

In our study students completed an astronomy lab using the Magic Leap 1, a wearable AR device consisting of a headset and controller. The lab contains a mix of short, recorded lectures and interactions with 3D models of the Earth-Moon system to teach moon phases, sizes and scales of the Earth-Moon system, and synchronous rotation of the Moon. In addition to collecting pre and post tests and a questionnaire, we wanted to create tools that allowed us to collect data on how students used and interacted with our AR application. Students were split into groups of four to five participants, and used the AR headsets to complete a lab about the phases of the moon while also filling out a paper packet.

In addition to the paper packet and pre-/post-tests, the software regularly records the position and rotation of the AR headset and controller, as well as tracking certain events like button presses and progress through the lab, among other things. Once individuals completed the lab, the data was uploaded to the cloud, then redownloaded and analyzed later.

We present the initial results of our measurements of learner engagement here, including the time on tasks with each lab section. Initial analysis was able to track a number of user behaviors: sitting to work on the packet, differing lengths of time spent on sections of the lab, how they interacted with the AR user interface, and how they tended to partially remove the headset. We anticipate that further insights can be built on top of this data, like levels of engagement, and predictors of learning. Ultimately this data can be compared to learning outcomes as measures in pre-/post-testing.

This material is based upon work supported by the National Science Foundation under Grant No. 2017011.

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Promoting STEM education in higher education through an interdisciplinary approach for early childhood education students

Seok Jeng Jane Lim and Karen Reed (Middle Tennessee State University)

Introduction

To prepare our preservice PreK-3 teachers better academically for career and life, there has been a movement and push towards integrating STEM education in Middle Tennessee State University. Integration of STEM concepts into the curriculum is intended to encourage critical thinking, problem solving, and collaboration as our students face an increasingly diverse and complex world. The Tennessee Department of Education, under the direction of the STEM Leadership Council, rolled out STEM standards for K-12 education beginning with the 2018-2019 school year. Recommendations included creating new modules that integrate the STEM standards, as well as providing both classroom and externally based hands-on learning opportunities for K-12 students (TN Department of Education, 2018). With this change at the elementary and secondary levels, it was thus imperative that higher education also integrate STEM standards into the curriculum.

One obstacle, however, is that studies have shown that most teacher preparation programs do not have a strong focus on STEM education (Schmidt & Fulton, 2017; DiFrancesca & McIntyre, 2014; Teo & Ke, 2014). Sondergeld, Johnson & Walten (2016) suggested that for impactful and sustainable K-12 STEM education, a partnership model should be adopted. Using this model, we intentionally redesigned a course syllabus to integrate STEM education through a partnership with the MTSU library's Makerspace, as well as a community partnership with our local Boys & Girls Clubs. STEM education lends itself well to using an interdisciplinary approach in combining different disciplines and providing service to community partners.

Research questions

Specifically, three research questions were targeted in this study

1. What is preservice teachers' perception regarding the use of makerspace at MTSU Walker Library?
2. What is preservice teachers' perception regarding the use of an interdisciplinary approach in STEM education?
3. What is preservice teachers' perception of bridging theory into practice?

Methodology and Timeline

An eight questions pre and post questionnaire were administered on 20 students using Qualtrics. The timeline for this STEM integration started with planning and course redesign in summer 2019, and implementation in the fall 2019 semester. Data were analyzed in Spring 2020.

Summer 2019 (Course redesign and seeking partnerships)

The course redesign was ECE 4370: Effective Instruction. This class is an in-depth study equipping early childhood educators with experience in planning, implementing, and evaluating the programs and curriculum used with young children in their natural educational environments. The foundations for this course are developmentally appropriate practices in children's settings that are inclusive and diverse. The final project of the course involves applying the knowledge acquired during the semester to planning and delivering a classroom lesson for K-3 children in a local elementary school.

As part of the course redesign, several STEM-centered enhancements were made. It was decided that an essential component of the lesson delivery would be a student-created manipulative or teaching tool produced in the library's Makerspace. Walker Library's Education Librarian was asked to help students get ideas for this task by demonstrating various teaching manipulatives found in the library's specialized Curriculum library, as well as showing students various lesson planning resources. Creation of the teaching tool and deployment of the lesson would be the culmination of students' newly-honed library skills. Working in partnership with the library's Education Librarian, dates were set in fall 2019 to ensure that students could be trained in time to use the equipment prior to production of the teaching tool.

At the same time, the instructor for ECE 4370 wanted to ensure that students can bridge what they have learnt in theory to practice. A collaborative partnership with the local Boys & Girls Clubs was sought as the field experience. The Boys & Girls Clubs of Rutherford County (TN) was chosen due to their close proximity to the MTSU campus. This location would ensure that the preservice teachers could work with the Club's children and then get back to their classes on campus on time.

Fall 2019 (Implementation)

During the fall 2019 semester, preservice teachers gained knowledge in planning, implementing and evaluating curriculum using an interdisciplinary approach integrating STEM education. They signed up for training at the library's Makerspace, and later worked in pairs to build prototypes for their lessons on STEM.

Data Analysis & Results

Using SPSS, results were coded using T test for significance and themes. This whole experience taught the preservice teachers many valuable skills such as the new knowledge gained from the use of Makerspace, using an interdisciplinary approach in integrating their knowledge and bridging theory into practice.

Conclusion

To ensure that our nation is equipped with the skills and knowledge of the high demand STEM-related careers, it is imperative that higher education take the lead in preparing preservice teachers. University educators need to show explicit connections in our syllabi to integrate STEM education into the curriculum; additionally; we need to seek opportunities for partnerships with community members and across disciplines. In this way, we are modeling for the preservice teachers what they can achieve when they are in their future diverse classrooms of K-12 students.

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A community of practice for STEM education graduate students: Lunch and learn

Tim Ransom, Jessica Manning, and Randi Sims (Clemson University)

Motivation and Introduction:

Support from a community is important to graduate student success [1]. Specific instances of communities that center around learning have been shown to increase retention rates [2] and communities of practice have been linked to effective learning and creation of knowledge [3], [4]. The opportunities communities of practice create and facilitate would likely function as a method of increasing agency for graduate students [5]. Our Engineering and Science Education department at Clemson University has developed a semi-formal community of practice and has subsequently used this weekly "Lunch and Learn" meeting to help develop graduate student agency. This work presents the current state of this community and highlights the major developmental decisions made. We also present an analysis of graduate student perspectives on the support of the community and its potential.

Study outline:

This work presents the Lunch and Learn space as a case study for developing and adjusting a graduate studies community of practice. This study illuminates decisions made intended to help develop researcher agency among the graduate students. We utilize the community of practice lifecycle as described by Wenger et al. [6] to trace the development of the community and to highlight important adjustments in the facilitation. This case study utilizes interviews from current members of the community and consults with individuals who hold institutional knowledge regarding the space. To discuss the effectiveness of our lunch and learn program, we pose the following research questions**: (1) how do members of Lunch & Learn feel the space has or has not supported them and (2) what do members of Lunch & Learn feel would better support them moving forward**.

Data analysis:

Semi-structured interviews are underway with current graduate students about their involvement in Lunch and Learn. Interviews will then be transcribed and coded by three researchers, with codes checked for inter-rater reliability above 70%. Collected data will have a thematic analysis conducted to identify relevant data to our research question. Special attention will be given to participants' contextualizations, reflections, and desires for future adjustments about Lunch & Learn.

Context of this case study:

This space was initially entirely informal and grew out of discussions graduate students held while eating their lunches. Our department covers all of STEM education research, so the discourse features a wide variety of perspectives. Eventually, this space became more structured and conducted at a set time (around lunchtime on Fridays), gaining its name "Lunch and Learn". This aligns with a formation of a community of practice. As the number of graduate students grew, this discussion space was officially sanctioned by the department who then provided official room reservations to facilitate the discussions.

The formalization of Lunch and Learn led to the development of explicit goals and has already provided benefits of recruitment and engagement for the graduate student population. Lunch and Learn has also grown to accommodate more participants, leading to a point of decision regarding the goals and structure of the time. Wenger et al. write about the balance a nacient community of practice must strike between professional and social topics of discussion for its long-term health. Lunch and Learn has been intentionally directed towards professional or social topics depending on the needs of the graduate students at the time. For example, during the social isolations of the COVID-19 pandemic we chose to host more social events to help supplement the missed community development.

We have shifted our meeting medium from exclusively in-person to hybrid digital and physical to accommodate part-time and long-distance students, long-distance faculty, and students from different institutions.

During the COVID-19 pandemic lockdowns our group intentionally shifted to holding more social meetings. Before conferences or during periods of heavy workload, we have discussed professional development topics and the “denser” education research topics. These choices reflect graduate student agency as it determines the growth path of the community of practice. Solutions have been implemented to encourage group participation, develop graduate student agency, and further our researcher discussion skills. We will present obstacles that we have encountered and the resolution we employed during our time leading the group discussions through articles, Ted Talks, and seminars.

Current goals of Lunch and Learn include: practice of skills related to technical research discussion among and between ESED graduate students and faculty, reviewing relevant literature, and exposing graduate students to topics outside of their individual research topics. Lunch and Learn is explicitly organized by two graduate student leaders appointed by the head of the department for a period of two years. These organizers use past experiences to select and curate topics of discussion for the group, collating suggestions from graduate students.

Preliminary results:

Interviews collected from the research participants showcase several possible interpretations of the utility of Lunch and Learn. For some graduate students, it is a primarily social activity and a way to interact with peers and faculty. For others, the space is a way to reify their researcher identities by engaging in technical discussions within a safe space. Participants indicate that Lunch and Learn is a way to fight against siloing research groups within the department by having regular contact with individuals outside of their typical research groups.

Our preliminary participants have outlined several possible perspectives regarding their experiences in Lunch and Learn. These experiences had several similarities to broader graduate student experiences reported in the literature. We believe that our analysis will reveal practical advice from participants on facilitating a semi-formal research discussion space. We also anticipate that interviews with Lunch and Learn participants will unveil some previously unknown challenges associated with Lunch and Learn engagement amongst graduate students. With these results, we hope to develop additional goals and adjustments for Lunch & Learn to support graduate student community and agency development.

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A quantitative analysis on the effects of COVID-19 in associate programs versus bachelor programs using initial written exam scores for aircraft mechanics

Collin McDonald (Middle Tennessee State University)

The Coronavirus Pandemic has obviously affected the education system resulting in new mediums of presentation, alternate forms of participation, and a gambit of novel issues educators must address. These challenges have been felt at various magnitudes at every level of education from early elementary through post-secondary education. In a recent study on the Federal Aviation Administration's (FAA) written test scores for aircraft mechanics, a statistically significant difference was noted between students testing from programs that offered accelerated courses or associate degrees compared to those offered at colleges and universities in coordination with bachelor's degrees. Traditionally, students seeking accelerated education to enter the workforce sooner pursued the two-year training opportunities rather than those desiring a degree granting program such as a four-year university or college. A variety of reasons for this were explored.

There are 17 universities in the United States that offer an aircraft maintenance degree including FAA certification in addition to a bachelor's degree. All 17 of these schools were selected for data analysis. There are 158 schools that offer either a certificate of completion or associates degree in a two-year time frame in the nation. Twenty (20) of these (12.7% of the total population) were randomly selected for analysis. Data was taken from each quarter from 2016 Q1 through 2022 Q1 from both types of programs and analyzed using a variety of statistical tests. These tests resulted in a statistical significance (p-value = 0.0077) between the test Means of two-year programs versus four-year programs. The data concluded that while COVID-19 affected both levels of education, there is statistical evidence that there was a difference between test results posted from the four-year programs and two-year programs sampled.

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Biological thinking: A comparison between majors' and non-majors' mindsets

Kendra Wright and Jaime Sabel (University of Memphis)

Mindset refers to how students view their intelligence. Students' mindset also influences how often students engage in metacognition which is the ability to think about our own thinking to recognize how much we understand. Students who have growth mindsets will continue to think about what they are learning and how to better prepare themselves for exams. However, students with a fixed mindset tend to avoid situations in which they might struggle or fail because these experiences undermine their sense of intelligence. Differences in how students perceive the biological world are defined by many things such as students' prior experience, misconceptions, and external/internal factors. Understanding the relationship between students' beliefs and their abilities will provide important implications for students' metacognitive skills.

In this study, we compared students in a non-majors' introductory biology course to students in an introductory biology course for majors. We used qualitative analysis of reflection papers to gain a better understanding of whether students' mindsets shifted in Biology of Cell from the beginning to the end of the course. We also used qualitative analysis of interviews to investigate whether biology majors' mindsets changed as they progressed to upper-division courses. Findings show that incoming majors and non-majors have similar ideas coming into their first biology college course. Several students within both cohorts relied on their prior experience while preparing for exams. Students taking the non-majors' course were able to make more general connections with the lecture material, while in the course for majors, fewer students made those connections. We also found that within upper division courses, many students' mindsets became fixed due to a lack of interest and understanding while preparing for exams. We will discuss these findings and related findings at the conference.

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Engagement in metacognition among undergraduate biology students

Alixandria Kirkendol and Jaime Sabel (University of Memphis)

How a student utilizes a study method, comprehends the subject, and prioritizes learning can all be used to differentiate how students engage in metacognition. Metacognition is the process of thinking about one's own thinking and understanding. When a student is aware of their own understanding, they can make improvements to study plans, and make adequate changes to learning methods. These changes can result in students reaching greater comprehension, understanding the material and achieving higher grades on exams and in courses.

At our university, there are five core biology courses required for the biology major: General Biology I, General Biology II, Cell Biology, Genetics, and Evolution. Students in each course participated in surveys and interviews during the course, answering questions related to the principles of metacognition. In our analysis of these surveys and interviews, we asked the following research questions: (1) What are the characteristics of different levels of engagement in metacognition?, and (2) What are the themes that emerge across all levels of engagement in metacognition?

Responses from individual students were classified into four metacognitive levels as proposed by Stanton et al. (2015): Not Engaging, Struggling, Emerging, and Developing. We examined trends in responses within each of the four levels to identify any defining characteristics. We found that there are three overarching concepts that vary between all four levels: 1) the ability to identify poor study habits and capability to make changes, 2) the emphasis placed on grading and how it affected study effort, and 3) the focus on comprehension rather than rote memorization. We then explored the presence of the three dimensions of metacognition, as defined by Grotzer and Mittlefehldt (2012): Intelligibility, Plausibility, and Wide-Applicability. We are currently working to identify which dimensions are the most abundant in each metacognitive level, as well as demonstrate the dimensions that each level should be integrating to enhance their metacognition development. In this presentation, we will discuss the four levels of engagement, the trends we found among students in each of these four levels, and the overarching trends of metacognitive dimension presence. Next steps include developing an instrument to measure students' metacognition engagement. These findings will be of benefit to instructors and metacognition researchers in that it further defines how metacognition develops and the characteristics of metacognition students exhibit.

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Investigating undergraduate students' engagement in systems thinking using causal maps

Sedra Sous and Jaime Sabel (University of Memphis)

Undergraduate biology classes must prepare students to engage in an increasingly interdisciplinary field where they will need a foundation of scientific understanding to make informed decisions about the science they will encounter in their careers and everyday lives. To develop this foundation of scientific understanding, students need to integrate their ideas about individual concepts into thinking about complex biological systems. To investigate the extent to which undergraduate students engage in systems thinking, we conducted a pre-post study with students in a required undergraduate botany course at a small liberal arts college in the Midwest. All students in the study were asked to complete a causal map at the beginning and end of the course. Casual maps are similar to concept maps but demonstrate cause and effect relationships rather than other connections included in a concept map. Students were also asked to answer two questions about their causal map: (1) Explain how your causal map demonstrates the relationships of plants and the environment? and (2) If someone, a non- scientist, asked you to explain how plants connect to everyday life or situations, how would you answer using your causal map?

To evaluate the questions students answered after drawing their causal maps, we used open coding to determine common topics among the answers. We also used the framework for systems thinking developed by Mehren et al. (2018) as utilized by Mambrey et al. (2019). This framework is defined by three stages of progress toward developing skills of system thinking. At Stage 1, students provided a vague level of understanding when trying to comprehend the benefit of drawing causal maps. At Stage 2, students made moderate connections between plants and the environment but did not elaborate with specific examples that would help them to create broader connections. At Stage 3, students identified multiple different connections relating to plants and the environment. These connections were complex and identified specific examples. Ultimately, results showed that the majority of students did not draw upon specific connections when answering the questions, but rather leaned more towards broad areas of connection.

This work highlights the difficulties undergraduate students have with engaging in systems thinking but provides important insight into the particular areas in which students do engage in more complex thinking and areas in which we can specifically target with instruction and intervention. As such, it will be of interest to SSERC attendees and the broader science education community.

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A curriculum analysis of how students work with data in open Sci Ed and CK-12 units

Amanda Garner and Joshua Rosenberg (The University of Tennessee, Knoxville)

Introduction and Purpose

As many science education scholars know well, eight practices comprise the science and engineering practices described in the Next Generation Science Standards (NGSS Lead States, 2013). Many have been the focus of substantial research and (curricular) development. For instance, consider the practice of developing and using models. This practice—one of the eight articulated in the standards—has been the focus of research spanning multiple years and scholars from different sub-communities in science education research (e.g., Campbell et al., 2011; Lehrer & Schauble, 2004; Passmore et al., 2002; Schwarz et al., 2009; Windschitl & Thompson, 2006). As another example, there is an extensive body of work on the practice of argumentation (Berland & McNeill, 2010; Duschl & Osborne, 2002; Manz, 2015). In short, we know a lot about both epistemic and practical aspects of many of the science and engineering practices. But, one practice about which we know less is the fourth: the analysis and interpretation of data. While scholars have documented the data source and technologies teachers report using (Rosenberg et al., 2022) and what teachers do when their students analyze data (Banilower et al., 2018) and how there are differential affordances of first- and second-hand data (Hug & McNeill, 2008), there are fewer practical strategies to guide what teachers do with their students around the analysis and interpretation of data. There is no clear definition of data literacy (Gebre, 2022; Wilkerson & Polman, 2020). In short, there is little research in relation to the use of data in science curriculum. There is some research into data literacy and what would be the framework for teaching it across content areas (Shreiner and Guzdial, 2022, Matuk et al., 2022), but this work is of limited utility for understanding what science teachers and students do to work toward what the NGSS suggest in K-12 science classes.

The role of data in the NGSS invites a question: even if we have less guidance for the practice of analyzing and interpreting data, what do science curricula call for (and support) students to do? Scholars in other disciplines have engaged in curricular analyses to establish a foundation for how teachers and students are supported to work with data in extant curricula (Lee & Delaney, 2021). Such a study can raise both opportunities and challenges for what teachers presently do and how researchers can support teachers' implementation of this practice. If, for instance, curricula ask teachers and students to analyze large, complex (even messy) data sets, how supported are teachers with digital technology and teaching practices to support their students? And if curricula primarily call for students to work with small, already-prepared data sets—and to analyze and interpret the data in relatively narrow ways—to what extent are the calls in recent science education reform documents being met?

This study is intended to begin to answer these questions through a curriculum analysis of two widely-used science curricula. More specifically, the purpose of this study is to document what data is used and how and why it is used within middle school science curricula. We use OpenSciEd's 7th grade curriculum and CK-12's 7th grade life science curriculum, selected both because of their accessibility and because they represent two different approaches to both the design and use of curricula (OpenSciEd being very comprehensive in scope and detailed in contents, and CK-12 being finer-grained in scope and more flexible in how it is intended to be used). The following two research questions (RQs) guide our study.

1. How are students supported in different aspects of analyzing and interpreting data through the curricula?
2. What sources of data are utilized in widely-used middle school science curricula?

Method

We chose two open source curricula to measure the use and type of data in a 7th-grade life science unit. CK12 was chosen because it is an open-source curriculum that has been available for 15 years. It is a widely used curriculum and offers the flexibility for educators to build their own or utilize textbooks that are readily available. It is easy to use and can be used within all the major LMS throughout the United States. CK 12 offers an entire 7th-grade curriculum aligned with NGSS standards.

For this study, we carried out separate analyses for RQs #1 and #2. For RQ #1 on how students analyzed and interpreted data, Our first step was to identify the aspects of the practice of analyzing and interpreting data at the middle grades level in Appendix F of the NGSS (NGSS Lead States, 2013). Specifically, the NGSS describes eight different aspects of analyzing and interpreting data, such as "Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships." Using these descriptions, we identified whether an activity did or did not call for students to engage in that aspect of the practice, recording these in a spreadsheet by level for later analysis.

From there, for RQ#2, we used those practices to identify what would be the data sources. We decided to focus on basic data types in way of text, graphs, charts, tables, maps, and other. Our other code is defined as things that support data literacy but do not necessarily fall within text, graphs, charts, or tables. The other distinction covers food chains and/or infographics. We decided to count data that is used in multiple lessons once. This means that if a graph was used in multiple lessons, it only counted as one piece of data. We looked through the materials for each lesson within the unit and recorded our findings in a spreadsheet for analysis.

Findings

RQ #1: The Aspects of Analyzing and Interpreting Data Students Engage In

Overall, Open Sci Ed had the most instances of data and had a range of data activities that covered all aspects of analyzing and interpreting data practices at least once. CK 12 had the least amount of data and the least covered within the standard aspects of analyzing and interpreting data practices. With respect to the type of data, Open Sci Ed had examples of each type of data. Maps, with eight examples, and Tables/Charts, with eight examples, were the most frequent followed by graphs, with seven, and other, with seven. Text was the least frequent at three examples. CK 12 had graphs as its most frequent, with two examples within the unit. Maps and other followed with one each. For size, Open Sci ed had examples within all three categories of small, medium, and large. The most frequent size within Open Sci ed was small with 21 examples. CK 12 only had four examples of small.

RQ #2: The Sources of Data Used in Middle School Science Curricula

Open Sci Ed far exceeds CK12 in the amount and usage of data within the unit of study. Within this unit, Open Sci ed covered all NGSS aspects of analyzing and interpreting data practices at least once while CK12 only covered four. CK 12's most prevalent data were graphs. These graphs were general and did not always show specific information. In fact, one graph showed population numbers and the other showed what a graph would look like in doing specific work with populations. Open Sci ed's most prevalent forms of data were maps and tables/charts. The tables and charts showed a mixture of data types. They were used to show quantitative information in addition to qualitative. They were used to structure information to support the learning objectives for the lesson. Graphs and other were the second most prevalent data included in the unit. Open Sci ed used several infographics to support data through visualization. The graphs included were mostly linear and had a high number of student-created graphs. Small data size was the most prevalent in both open access units. CK 12 only had a small data size. Open Sci ed did have medium and large sets but they were less prevalent than the small.

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Data analysis in science classrooms: Teachers' perspective

Omiya Sultana, Joshua Rosenberg (The University of Tennessee, Knoxville), Elizabeth H. Schultheis, Melissa K. Kjelvik (Michigan State University), and Aaron Reedy (DataClassroom)

Background and Purpose

For science educators, the Framework for K-12 Science Education calls for students to have opportunities to learn the standard data analyzing and interpreting techniques (National Research Council, 2012). These techniques include learning different types of graphs, and the identification of outliers in the data set. Along with data analysis and interpretation, the Next Generation Science Standards developed following the release of the Framework emphasize some other skills and abilities related to working with data, including collecting data, tabulating, and finding patterns in the data (NGSS Lead States, 2013). These skills are not regularly enacted by the teacher or practiced by the classroom students (Banilower et al., 2018; Kastens, 2015), and should be more frequent (Lee and Wilkerson, 2018). Skills related to analyzing and interpreting data are essential regardless of what careers students choose in the future (Kastens, 2015).

In our previous work (Authors, 2022), we explored the sources of data students and teachers use in science classrooms. However, we have not explored the type of activity students do and the challenges faced by teachers during data practice in the science classroom. Knowing about the types of activities teachers do and the challenges they face is important given the wide range of ways students might analyze and interpret data, from collecting and interpreting relatively small data sets to engaging in sophisticated visualizations of large-scale, even messy data sets. Further, teachers may face particular challenges that go under-recognized by those in the research, teacher education, and curriculum development sub-domains of the science education community. Therefore, the purpose of this study is to explore common data practice activities and possible challenges for data practice activity in the science classroom. The findings reported in this study will help researchers and curriculum developers know how teachers are enacting the curriculum in an intended way. Similarly, teacher educators will also know if teachers need any support or professional development to plan a lesson to implement this specific science practice. The specific research questions posed in this study follow.

1. What are the data analysis and interpretation-related activities that teachers report doing?
2. What challenges do teachers face during these activities?

Method

We used a survey research methodology to collect data in this project. First, we developed a survey consisting of items on demographics and the use of data. We used some available and validated survey items (from the NSSME+; Banilower et al., 2018). However, not every survey item that we needed for this study was available. Therefore, we developed some new survey items. The final survey instrument consisted of 11 questions on the use of data in the classroom and 15 demographic questions.

To analyze the qualitative data to answer RQ #1, we carried out a thematic coding process. In this process, two raters open-coded 25 of the same qualitative responses to a question to teachers about what a typical activity related to analyzing and interpreting data is like. These coders developed an initial coding frame and then carried out multiple rounds of inter-rater agreement, discussing and resolving all disagreements through discussion until a sufficiently high inter-rater agreement (93.5% agreement) was achieved. One coder then coded the remaining responses. From this analysis, we present the codes and their frequencies (separated by grade level). To analyze the responses to the fixed response item, we calculated the frequency with which each option (area teachers reported needing greater support or help) was selected by teachers, also separating these by teachers' self-reported grade level.

Findings

Teachers reported data visualization (50%) is the most reported activity. As an example of how teachers described this activity, a response to the question about when students are analyzing and interpreting data, and what type of activity students usually do: "Most often hand graph using graph paper. They then estimate a line of best fit and find a slope." We coded responses as data visualization when students create a graph or a diagram using any tool (i.e., google Sheets) or in the paper. The educators also mentioned students analyzing any teacher-provided graph and identifying trends or patterns in the graph. We coded those responses as data interpretations along with interpreting data or tables. Data interpretation (39%) is the second most common activity as mentioned by the educators. A few other activities mentioned by the educators are data collection (35%), data summary (27%), data application (21%), and data curation (15%).

Teachers reported that evaluating data quality and trustworthiness (75% of all educators) and using data to support claims (69%) were the most commonly-reported topics for which teachers needed additional help or support; data ethics (47%) and data documentation (40%) were reported far less frequently, with small differences across grade levels.

Discussion

Educators reported that data visualization is the most common activity that students do during analyzing and interpreting data in the classroom. In this code, data visualization is defined as graphing firsthand or providing data. Teachers have used both paper-pencil and digital tools to involve students in the graphing activity. Researchers argued several benefits of constructing graphs in science classrooms. According to Matuk et al. (2019), plotting graphs helps students to link science ideas with contexts. Graphing activity not only helps students understand science better, but also helps science teachers to understand students' level of understanding or misunderstanding (Vitale et al., 2019). Despite having several benefits, is all graphing activity a part of analyzing and interpreting activity? Rivet and Ingber (2017) argued that "graphing for the sake of graphing" is not a practice of analyzing and interpreting data. They suggested that creating a visualization or graph without a scientific purpose should not be considered as analyzing and interpreting data. However, from many responses, it seems that students only create a graph or any visualization without trying to answer a question or make a connection with a particular scientific context. For example, one teacher responded “Enter data from an experiment and make a graph”.

The above discussion suggests that teachers are considering data visualization as an analyzing and interpreting data activity. However, there is room for teachers to be supported to do even more when it comes to how their students work with data. This opportunity suggests the need for a greater emphasis on what is a longstanding activity in science classrooms—analyzing data—that may be even more important to foster given the roles of data in science and students’ lives.

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Lessons from our fathers: Increasing STEM grit among underrepresented groups

Twianie Roberts, Orville N. Bignall (Tennessee State University), and Sibyl Moore (Retired)

The 13th amendment (1865) formally abolished slavery in America by stating, “Neither slavery nor involuntary servitude... shall exist within the United States, or any place subject to their jurisdiction.” After Nat Turner led a bloody revolt, many states passed laws forbidding teaching slaves to read and write. Once slavery ended, Jim Crow Laws and Separate but Equal policies, promoted a lower standard of education for African Americans. In some instances, African Americans were not allowed to attend colleges or universities. One example is the University of Mississippi’s History of Integration. Nearly 100 years after slavery was abolished in America, Title IV of the Civil Rights Act of 1964 was passed. Title IV of the Civil Rights Act of 1964 prohibits discrimination in public schools because of race, color, religion, sex, or national origin. Public schools include elementary schools, secondary schools and public colleges and universities. African American’s education, attendance at public universities and attainment of STEM degrees must be viewed in light of the historical context of slavery and discrimination. In spite of these challenges, tremendous strides have been made in STEM areas by African Americans who have worked towards both scientific and discriminatory breakthroughs. This session will present a model for increasing the vicarious self-efficacy of African American K-12 students by examining the professional achievements and Grit of African American STEM professionals.

Psychologist Albert Bandura developed the concept of Self Efficacy. It is defined as an individual’s belief in their capability to exercise control over their own functioning and over events that affect their lives. It is a person’s belief in their ability to succeed in a situation. Self-efficacy is developed from four sources:

1. Mastery experiences – How well you have “Mastered” a task in the past.
2. **Vicarious Experiences – Seeing others “like you” succeed at a task.**
3. Social Persuasion – Receiving positive verbal feedback that instills within an individual that they can accomplish a task and
4. Emotional states – “The emotional, physical, and psychological well-being of a person can influence how they feel about their personal abilities in a particular situation.” (Bandura, 1977)

“Lessons From Our Fathers: Increasing STEM Grit among Underrepresented Groups” is a model that uses **Vicarious Experiences** – Seeing others “like you” succeed at a task. Within the model, K-12 students will view videos, read books or perform research on individuals “like them”, that have succeeded in STEM related fields in an effort to increase STEM self-efficacy. This model is highly reproducible for all underrepresented groups.

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The navigation of STEM and racial identities within marginalized graduate students and the influence of research mentors

Kathryn Hosbein (Middle Tennessee State University), Paulette Vincent-Ruz (New Mexico State University), Madison Gillis and Wanqi Feng (University of Michigan)

Recent publications within STEM communities highlight systemic racism in science and call on researchers to better address the disproportionate exit of racially marginalized students from STEM.[1–6] One way to address these calls is through the study of science identity, an important factor in the persistence of racially marginalized students.[7,8] While there have been studies that broadly explore science identities and its interaction with race in STEM,[8,9] there are no studies that report the specific influence of faculty mentors in the navigation of science and racial identities.

This project is guided by two overarching research questions: (1) In what ways do marginalized STEM graduate students navigate their science and racial identities within graduate school? and (2) How can faculty mentors support this development? The framework guiding this project is the critical physics identity framework (CPIF)[9,10]. While the CPIF is specific to physics, we use the racialized identity resources (RIR) from the framework and apply them more broadly to science identity[11] within this study. RIR are institutional structures that connect a person to a practice and provide insight into how these structures can differentially impact marginalized populations. When negative, RIR can present as discriminatory experiences and therefore negatively impact their science identity.

The framework and methodology in this study were rooted in a critical paradigm[12] to highlight the experiences of marginalized groups and foreground their assets to promote empowerment of marginalized individuals within STEM. The methods were purposefully crafted to ensure that lived experiences of marginalized graduate students in STEM were centered. University of Michigan graduate students in STEM were recruited via a survey sent through email. Students who reported a racial or ethnic identity as a central part of their identity were prioritized in this study. After participant selection, semi-structured interviews were conducted. Questions included those surrounding racial and science identities, RIR, and mentor support the graduate student has received in relation to their identities.

Interviews were transcribed and subsequently analyzed using a deductive coding scheme that was previously developed for RIR.[9,10] We then used the resultant codes to investigate what types of positive and negative RIR participants have experienced throughout their graduate career and the involvement of mentors in these experiences. Students described a variety of RIR within their graduate experiences. Examples of RIR that contributed to student science identity development included relational resources such as key relationships and ideational resources such as perceived images of who a scientist can be. Students shared examples of support that their mentors had provided in terms of their science identity development such as normalizing instances of failure. Experiences with mentors that negatively impacted students' identities were also shared. For example, multiple students described conflicts within their research groups that were discriminatory in nature with little guidance from their mentors in how to navigate these conflicts. During this presentation, specific examples of RIR and ways that mentors can support their marginalized students will be discussed.

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You gotta work, BASIL! Reimagining an established CURE to provide high-quality digital learning experiences that are intentionally equitable, inclusive, and accessible for all students

Arthur Sikora (Nova Southeastern University)

In recent years, Course-based Undergraduate Research Experiences (CUREs) have become increasingly valuable models to cultivate student interest in research, especially when few other research opportunities at an institution exist. Since the start of the COVID-19 pandemic, there has been the need to operate in an online environment while maintaining high standards. Biochemistry Authentic Student Inquiry Lab (BASIL) students hypothesize and test functions of enzymes from the Protein Data Bank with no known function, utilizing a combination of wet-lab and computational approaches. Here we describe how this CURE was adapted to an online format, simulating the lab environment using a low stakes iterative assessment. Using Google forms, students answer questions about experimental background, procedure and lab safety that correlate with published BASIL experiments. Using a mix of multiple choice, free response, and video/ image-based questions, students engage with the material at a deeper level despite not being physically present in the lab. These forms can function as self-contained experiments or pre-lab/post-lab assignments to enhance the in-lab experience.

The BASIL consortium is dedicated to developing high-quality teaching and learning experiences to reach and engage the modern learner. This CURE is flexible and has been found to improve the levels of personal comprehension and knowledge of STEM concepts and research design in students. These online modules provide another way for learners to reap the benefit of research-based courses in an ever-changing educational landscape. Built to equitably and inclusively reach and engage all students, these tools integrate intentional opportunities for community-building and interaction only possible in the digital environment. Novel strategies developed to accommodate all students will help to enhance exposure for undergraduate students to vital STEM research experiences and promote sustainability for institutions.

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Prospective secondary mathematics teachers' expectancy and value for enacting core teaching practices

Kingsley Adamoah, Christopher Bonnesen, and Jeremy Strayer
(Middle Tennessee State University)

Abstract

A central problem faced by secondary mathematics teacher preparation programs is the perceived disconnect between university mathematics courses and secondary mathematics teaching (Goulding et al., 2003; Ticknor, 2012; Wasserman et al., 2018; Zazkis & Leikin, 2010). In response, scholars have argued that these courses should provide teachers with explicit opportunities to connect university mathematics to the mathematics they will teach (Álvarez et al., 2020; Heid et al., 2015; Lischka et al., 2020; Ticknor, 2012; Wasserman et al., 2018). Literature shows that cognitive aspects do not alone explain what teachers can carry out; motivational aspects such as teachers' value commitments, willingness, and beliefs shape how they face the demands of teaching (Schoenfeld, 2010; Zee & Koomen, 2016). Hence, motivation is also an aspect of competence for teaching (Kunter, 2013); from this perspective, we focus our investigation on expectancy and value. Expectancy is the expectation of success at enacting a task in a specific situation (Wigfield & Eccles, 2000). As Bandura (1977) argued, a person's expectancy is one of the most important influences on human behavior. Value focuses on the utility, enjoyment, and personal fulfillment a person places on enacting a task (see Eccles & Wigfield, 2020, for a review).

Our study uses data from the Mathematics of Doing, Learning, and Educating for Secondary Schools (MODULE(S2)) project. The MODULE(S2) curricular materials are used to apply mathematical content to preparation for secondary teaching practice (cf. Bass, 2005; Stylianides & Stylianides, 2010) across four content areas: algebra, geometry, modeling, and statistics. The curriculum materials provide guidance both to instructors and to prospective teachers that encourages the enactment of two core teaching practices: (1) generating questions and discussions that promote student exploration of conjectures, and (2) learning about students' understanding through their explanations, justifications, and representations. At first glance, it would seem that teachers' expectancy and value would predict teaching and learning outcomes. However, there is little research in this area in mathematics, let alone in secondary mathematics. Therefore, we investigated the question:

How did teachers' expectation of success for and valuing of carrying out the selected core teaching practices in MODULE(S2) materials change over the course of a semester-long experience that: (1) coordinated instruction with those practices and (2) contained assignments that provided teachers opportunities to apply those practices to teaching?

We argue that when university mathematics instruction features these core teaching practices and the curriculum features opportunities for prospective secondary teachers to simulate those practices, the course has the potential to impact teachers' expectancy and value for enacting teaching practices. The data include 368 prospective secondary teachers' responses to pre- and post-term surveys that measure expectancy and value for selected core teaching practices using items on a Likert scale from 0 (not at all) to 5 (very much).

Overall, our analysis shows mean increases in teachers' expectancy and value for enacting core teaching practices. Across all content areas, effect sizes indicated non-negligible practical significance, with some effect sizes for each of expectancy and value indicating large practical significance. We conclude that teachers' competence – interpreted as a combination of cognitive, affective, and conative aspects – did improve. Therefore, it is more likely that these teachers will choose to enact those core teaching practices in the future.

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The influence of social interactions on student mathematical creativity in the high school classroom

Meghan Riling (Vanderbilt University)

All people need to create new mathematical ideas for situations that are personally effective (e.g., making financial decisions), or meaningful (e.g., engaging in music or fiber arts). That is, they need to be able to be mathematically creative. I define a creative mathematical action as one that transforms a given mathematical context by creating ways of doing or thinking about mathematics that were previously not possible for a given community of mathematicians (Riling, 2020). However, most instruction is designed to train students to use procedures or understand existing concepts (National Research Council, 1999; Watson, 2008). When students only experience mathematics as something created by others, they may not be empowered to apply and adapt mathematical ideas that could serve their needs and enrich their lives, which may be dangerous and dehumanizing (Gutiérrez, 2018; Su, 2017).

The existing approach to instruction perpetuates the belief that mathematical creativity is only possessed by the most "genius" of people (Mann, 2006; Poincaré, 1910; Simonton, 1999) or "gifted" of students (Kattou et al., 2013; Leikin & Lev, 2013; Sriraman, 2005). I argue that mathematical creativity is a behavior that is influenced by cultural norms, social interactions, and personal preferences, as shown in other fields (Csikszentmihalyi, 2014; Hanson, 2015). Studies support that student mathematical creativity can be impacted by social dynamics such as politeness (Chiu, 2008) or collaboration (Clack, 2017). Research must continue to explain how student mathematical creativity happens and is influenced by social forces.

In order to support teachers in nurturing all students' creativity, this study presents narrative analyses of student mathematical creativity drawn from high school mathematics lessons. The analysis incorporates contextual factors and utilizes a lens of creativity that illuminates complex relationships between students and teachers. This type of description is meant to offer mathematics educators insight into how to recognize and support their students' creativity. I ask: How do student interactions and behaviors impact the development of student mathematical creativity in the high school classroom?

Data Collection and Analysis

Data for this study was collected in high school classrooms in the North East of the USA. Lessons were audio- and video-recorded. Transcripts of lessons were analyzed by scanning for actions that could lead to the creation of new mathematics. These are those actions that students have taken using their own agency, rather than following disciplinary or classroom norms (Pickering, 1995). Until an action's new possibilities are realized, it only has the potential to be creative. Therefore, transcripts were also analyzed for evidence that students became able to think about or do mathematics because of an identified action with creative potential. I identified potential social influences on these actions by asking questions about the data based on a social interaction framework adapted from Engle et al. (2014): student mathematical authority, access to conversational floor, spatial privilege, group participation, and camaraderie. To strengthen my analysis of social factors, I also interviewed participating teachers. I analyzed a subset of student actions with creative potential in depth by writing narrative episodes about the actions. When writing these episodes, I worked to explain how all identified social factors influenced the student behavior related to the action with creative potential.

Summary of Findings

Here, I describe two episodes of student creativity. In one, vigorous discussion and student advocacy enabled a creative action to fulfill its potential as a small group of students proved a theorem that had previously eluded them. In the second, peers' indifference and obstruction prevented a student's action from fulfilling its potential. However, there was some evidence that the creative potential of the idea lived on. All student names are pseudonyms.

The first episode occurred during a freshman geometry class as students attempted to prove that when the midpoints of any quadrilateral are connected, they form a parallelogram. After many failed ideas, one student, Alex, took two actions with creative potential. First, she added a diagonal to the diagram provided by the teacher. Second, she reinterpreted the diagram as containing a triangle with a midline. She explained that this enabled her to apply the Midline Theorem to prove that certain line segments were parallel and of equal length, making the inner shape a parallelogram. She shared, "You see how that would be half of that? ... And then this is equal to this. And then with this one- ... Oh my god, we found a way, we found a way!" Her peers, two female students, were not convinced. They asked her many questions, especially doubting the relevance of the Midline Theorem. Alex responded to their questions, explaining herself in different ways and gesturing to different parts of the diagram. Their dialogue was rapid and overlapping as each attempted to control the conversation. Overall, Alex was successful in keeping the focus on her action and eventually explaining it in such a way that her groupmates were able to recognize the validity of her proof. They described "seeing" the diagram in a new way, suggesting that they were actively reorganizing their own understanding of mathematics.

The second episode occurred during an AP Calculus lesson introducing the rule for derivatives of exponential functions. As a small group of students was completing a table of values of $f(x)=2^x$ and its derivative, Delia chatted about video games. However, she suddenly said, "((gasp)) I see a pattern, I see a pattern!" She tapped repeatedly on her calculator until her peer, Dani, looked at it. She excitedly explained, "That is double that, I think it's because it's two in the front of the x, and then it's that (goes up to?) that, that (goes up to?) that!" Since Delia recognized the pattern of her own accord, it is an action with creative potential. Dani attended to Delia's explanation, but kept a straight face and then looked away, responding flatly, "That's so cool." Delia replied, "I don't know why it's doing that, just, it is doing that." After ten seconds of silence, Delia changed the subject. Later in the lesson, the teacher specifically instructed students to look for patterns in the table. Delia attempted to bring up her pattern, but Dani interjected repeatedly, complaining again about the lesson and physically invading Delia's space by attempting to poke her hair with a pencil.

In both episodes, the students who took the initial action worked to draw attention to their ideas with affective displays and continued to advocate for their actions: Alex by answering questions, re-phrasing herself, and adding gestures to the diagram, and Delia by continually trying to reintroduce her idea. Peer reception was different in the episodes. Alex's peers deeply considered her proposition, asking questions and attending to Alex’s explanations. Eventually, they actively changed their way of thinking. Delia’s peer did not consider Delia’s action and actively blocked Delia from discussing her idea. Hearteningly, Delia’s continual attempts demonstrate that although it was blocked, her action did continue to carry creative potential.

These two episodes demonstrate that creativity in the high school mathematics classroom is not an instantaneous spark. Instead, it can be a fraught, complex, drawn-out process that is critically impacted by the behaviors of both the student who has an initial idea of an action with creative potential, and the other students in their community.

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Will I ever use this? Closing equity gaps in math with utility-value interventions

Chris Hulleman, Yoi Tibbetts, Michelle Francis, Alison Lubin, Delaram Totonchi (University of Virginia), Kenn Barron (James Madison University), and LaDonna Young (Motivate Lab)

Students from underserved populations (e.g., first-generation college students, racially marginalized students) face substantial barriers to degree completion in introductory science, technology, engineering, and math (STEM) courses [1, 2]. To remedy this equity problem, a variety of interventions have been designed to improve the achievement and persistence of historically underserved students in STEM disciplines. For example, utility-value interventions increase students' math interest and achievement in four-year colleges [3, 4] and are particularly effective for first-generation and racially marginalized students [5]. However, more research is needed on the efficacy of utility-value interventions at two-year colleges, which enroll a majority of first-generation students. Additionally, the psychological processes through which these interventions impact STEM achievement and retention need to be further explored.

Utility-value interventions are designed to enhance students' perceptions of the usefulness of a learning task (i.e., increase student perceptions of course utility value) [4, 6-9], with the aim of improving their motivation, performance, and persistence in courses. The basic notion behind utility-value interventions is that helping students draw connections between course content and their daily lives will increase students' perceived utility for the course. For instance, several intervention studies enhanced students' perceived utility value for their course by asking them to write about ways they might apply course concepts in real-world settings [7, 8]. Results of these interventions suggested that engaging in these writing activities enhanced students' interest and academic performance in the course. Therefore, finding one's coursework relevant to one's life may serve as a psychological mechanism through which the intervention improves academic outcomes.

Method

In order to test the efficacy of utility-value interventions in community college mathematics, we embedded a series of reading, reflection and writing exercises (i.e., a utility-value intervention) to help students connect what they learn in gateway and developmental math courses to their lives and future careers. This double-blind, randomized study was implemented with more than 3,000 students in introductory math courses in community colleges in Florida (N = 2,699; 62% female; 39% Latine; 29.8% white; 22% Black; 5.9% Asian; 3.4% Indigenous, Pacific Islander, multiracial; 23% first-generation; 15% adult learners) and Tennessee (N = 696; 66% female; 71% white; 15% Black; 6.0% Indigenous, Pacific Islander, multiracial; 5% Latine; 3% Asian; 43% first-generation; 37% adult learners). The intervention activities took students about 30 minutes to complete and were developed as a partnership between researchers at the University of Virginia and community college math faculty. We randomly assigned students to a utility-value or control condition. Students in the intervention condition were asked to read quotes from previous students about how math was important to their lives and rank these quotes based on how relevant they found them, then to write about how they could use math in real-world scenarios. Students in the control condition were asked to summarize a math concept they recently learned in class. We were primarily interested in students' learning outcomes in their math courses, including math course grades, pass rates and withdrawal rates. We were also interested in whether the interventions increased the perceived relevance of math (e.g., “What I’m learning in this class will be useful to me in my future career”) and whether these changes in perceived relevance explained the impacts of the intervention on academic outcomes.

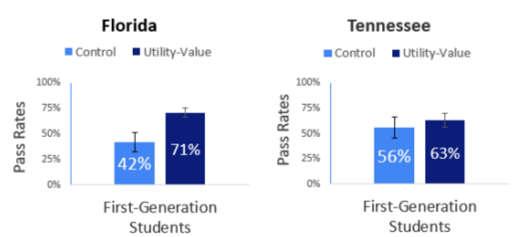
Results

Consistent with prior research, we found that the utility-value intervention worked better for some students than others. In both samples, the utility-value intervention significantly increased course grades (**β** = 0.247, p = 0.06, d = 0.60) and pass rates (**β** = 0.280, p = 0.05, d = 0.15) for first-generation students (See Figure 1). Specifically, the boost to grades was an average of 0.33 GPA points, and the boost to pass rates was an average of 40% across both samples. We also found that the intervention boosted students’ perception of the relevance of math to their lives. In both samples, we found that participants increased their perceived relevance more when randomly assigned to the utility-value condition than the control condition. This change in relevance was especially strong for continuing- generation students (**β** = .37, 95% CI [.20, .54]). Specifically, first-generation students in the control condition actually experienced a decrease in relevance over the course of the semester, whereas students randomly assigned to the utility-value condition experienced a large increase in relevance. Mediation analyses revealed perceived relevance was a significant mediator of intervention effects (**β** = .273, 95% CI [.181, .367]).

Discussion

Our results signal that brief instructional practices that support student motivation in general, and the perceived relevance of math in particular, could be effective at increasing pass rates in community college math. For first-generation students in particular, our evidence suggests that in the absence of the utility-value intervention, these students experience a significant decrease in math relevance from the beginning to the end of the semester. Such a decrease in relevance is foreboding for their future success given the strong relationship between perceptions of relevance and academic outcomes. Instead of focusing on what students lack, our results highlight what is lacking in the learning context — offering students the opportunity to make connections between what they are learning and their lives. This small tweak to the learning context can improve learning outcomes, particularly for first-generation students enrolled in introductory math courses. Because the activities were integrated into existing mathematics courses, large-scale implementation does not require drastic changes to curriculum. This means that the utility-value intervention has the potential to be implemented at institutions across the nation as a complement to broader structural reforms.

Figure 1. *The effects of the utility-value intervention on pass rates by student generation status*



Note: Error bars represent +/- 2 standard errors; both comparisons above are statistically significant at least $p < .05$.

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The trajectory of science teachers after the leadership program

Andrea Reeder and Gregory T. Rushton (Middle Tennessee State University)

Background

Leadership is the "affecting of people or groups to develop their potential as well as the ability of achieving organizational goals with voluntary efforts" (Liao et al., 2017, p. 595). It is impacted by cultural, cognitive, and contextual factors that shape performance (Ferris et al., 2007). Changes that occur over time in a leader's behavior define leadership trajectory (Fagin, 2000). In the sphere of leadership are science teacher leaders (STL) whose actions and trajectories are influenced by cultural, cognitive, and contextual factors. Leadership training, personality, and school environment are cultural elements that impact the goal of being an STL, a contextual factor (Lambert, 2003; Rajagopaul, 2007). Self-efficacy and professional satisfaction are cognitive attributes that also shape the purpose of being an STL (Lent et al., 1994).

Significance

Evidence exists that cultural, cognitive, and contextual elements independently influence STL actions (Alegado, 2018; Hirsh & Bergmo-Prvulovic, 2019; Lambert, 2003; Rajagopaul, 2007), but what is unknown is how the interaction of these factors shapes the leadership trajectory of STL developed in a teacher leadership program (TLP). A TLP is optimal for leadership development because it provides tasks connected to learning leadership and aligned to teaching approaches (Darling-Hammond et al., 2017; York-Barr & Duke, 2004). Knowledge of the leadership trajectory informs TLP facilitators about the type of training needed by science teachers to function as STL in their school because the methods used in TLP develop the STLs' identity, which shapes their leadership trajectory (Bianchi, 2017). In addition, this study addresses what teachers learn and use from professional developments.

Research Question

This study examines the leadership trajectory of STL developed in a TLP to investigate the factors that shape their leadership performance in their schools. The research question guiding this study: How does the interaction of cultural, cognitive, and contextual attributes affect the leadership trajectory of STL?

Data Analysis

Longitudinal views of 4 STL are presented in a multiple case study. The participants taught in schools with diverse populations from a large metropolitan area in the southeastern United States. Five years of data inform this study: from 2018 to 2021, the teachers participated in yearly individual interviews, and in 2020, the participants' peers, administrators, and district officials were interviewed. The interviews were analyzed using first and second-cycle coding strategies (Saldana, 2015). The first cycle of coding used three codes (cultural, cognitive, and contextual) identified by Truyens (2021). Second coding focuses on thematic analysis using themes developed from the conceptual framework, Social Cognitive Career Theory. These themes were the TLP, self-efficacy, professional satisfaction, personal attributes, school culture, career goals, and I am a science teacher leader.

Findings

The findings are presented based on the themes.

TLP and Self-Efficacy

The teachers left the TLP with high self-efficacy that they could be STL. Tess's comments reflect the group's sentiment when she said " I do think the [TLP] helped me ...it gave me a lot of confidence" (2018 interview).

Professional Satisfaction and Being and STL

The interaction of professional satisfaction and the goal of being an STL, however, resulted in Tess not being an STL. She transferred schools to "avoid the responsibilities of being a teacher leader " (2018 interview).

Personal Attributes, School Culture, and Being an STL

Ashley left the TLP believing that being an STL would provide her professional satisfaction. The interaction of her personality and school caused her to transfer schools twice. She said, "I have way more outside-of school friendships....It's really important as a teacher to have people that you trust and respect" (2020 interview). In her second school, Ashley is an informal teacher leader, serving on school committees and leading her professional learning community.

The TLP helped Natalie develop her personal attributes, so she had the skills to navigate her school's culture. She said, " I never realized .... I have a very dominant, scary, intimidating personality." In the program, Natalie read a book taught how to engage with her colleagues. Natalie's trajectory showed her obtaining a formal position as a STEM department chairperson. Finally, John had a personal attribute that was not modified during the TLP. His attitude prevented him from becoming an STL in his school. He said, "I've been a thorn in the side of the administration... questioning a lot "(2021 Interview). John's colleagues, however, regard him as being negative.

Conclusion

The four STL had different leader trajectories. Tess decided not to pursue teacher leadership. Natalie became a formal teacher leader and Ashley became an informal STL. John believed himself to be an STL, but his peers did not view him as one. The interaction of cultural, cognitive, and contextual elements offers a lens to explain their paths.

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Implementation of the EOP model guided by the Renaissance Foundry Model

Pedro Arce (Tennessee Tech University), Andrea Arce-Trigatti (Tallahassee Community College), and Dipendra Wagle (Tennessee Technological University)

This contribution provides a preliminary statistical analysis of student data collected as a pilot relating to efforts made to magnify the focus on Sustainability in engineering curricula at the Department of Chemical Engineering of the Tennessee Technological University. Using the Renaissance Foundry Model (i.e., the Foundry) student- teams develop prototypes of innovative technology to address societal challenges as required outcomes in the courses reviewed. The analysis presented provides an overview of the degree to which student prototypes from these courses aligned with current sustainability efforts as well as areas for improvement. Based on these pilot projects, a proposal to systematically incorporate the Engineering for One Planet (EOP) model into core components of the design process in select chemical engineering courses was developed. The integration of the EOP model as a structured approach to sustainable design was incorporated to help guide student-teams developing such prototypes to address societal challenges as part of their formation as a holistically- trained professionals. An overview of this analysis, the efforts of the EoP proposal, and connections to the Foundry Model are provided. Preliminary implications related to holistic engineering education efforts and socially relevant learning are also presented.

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Computational thinking: Engaging students in STEM in the post-pandemic era

Tisha Gaines (Belmont University)

In an age where self-expression is limited to emojis, hashtags and TikTok videos; an instant connection is needed to provoke student interest. However, students' attention levels vary widely based on factors like motivation, emotion, enjoyment and time of day [4].

As the COVID-19 pandemic progressed, the number of Zoom screen time hours was added to this list. As a result, the incredible task of educators over the past two years required transitioning to a student-centered learning experience that was simplified, interactive, and adaptable. Using Computational Thinking Techniques (CTT), we implemented instructional strategies which assisted students in decomposing STEM course content into manageable concepts to recognize patterns, use abstraction and construct feasible solutions for real-world problems [5]. This model will allow us to build upon the current positive student outcomes seen in grade improvement, student and instructor rapport, as well as content retainment via engagement. Research has indicated that, " Quantitative and data-centric problems can be solved using computational thinking and an understanding of computational thinking will give students a foundation for solving problems that have real-world and social impact [3]." Continuing our efforts with the use of Computational Thinking Techniques (CTT), we focused on five participants during a summer program that assisted students in STEM topics to observe if similar outcomes can be seen for research engagement. The participants selected were both high school and university undergraduate students [1].

Projects that we highlighted included: "Predicting Facial Masking Efficacy Using Wireless Sensor Networks" , "Object Recognition using Color Coding Detection" and "Environmental Impact in Visual Sensor Networks Based on Energy Consumption" which had both mathematics and computer science elements. Plans to engage larger undergraduate cohorts with CTT will be integrated into intro-level computing, data science and mathematics courses as well as Big Idea micro-projects during the Spring 2023 semester [2]. The data obtained in this study assisted in evaluating our research question's goals seen below.

1. How can computational thinking improve student engagement for STEM course content via in-person and online learning?

2. How can computational thinking techniques be used to improve engagement in STEM research projects in secondary and undergraduate students ?

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Informal STEM event impacts on preservice teacher volunteers and families

Nyasha Dzenga, Shawn Hinkel, Carey Wilson, Jennifer Meadows, and Jane Baker
(Tennessee Tech University)

Since the launch of Sputnik, the United States has pushed for integrated STEM education (Bybee, 2013). Integrative STEM practices promote student collaboration, transfer of knowledge, and other 21st-century skills students need for success in their future potential STEM jobs. Tannenbaum (2016) stated, "In STEM 2026, integrated STEM teaching and learning experiences are incorporated throughout the P–20 continuum and may occur in school, in an out-of-school program or activity, throughout a curriculum or in a single course, or be reflected in a schoolwide approach to STEM education" (p. 13).

In addition, Tennessee has created the Best for All initiative. This initiative promotes literacy for students and provides teachers with research that indicates best teaching practices (TDOE, 2022). For STEM education, literacy also plays a significant role in student achievement. This study may add to the literature regarding STEM literacy within STEM education.

Above and beyond this, The Handbook of Research on STEM Education presents in-depth research on many areas of STEM (Johnson et al., 2020). Within this handbook, STEM outreach events are brought up multiple times. However, these programs are geared only towards children (student) learning or teacher facilitation research. Parent involvement within the context of STEM education is almost entirely ignored. In addition, Johnson et al. (2020) indicated that preservice teachers and STEM education teachers need more method courses that help them see the importance of STEM literacy for all students. By gaining insight from preservice teachers and families about the impacts these informal events have, this information may promote future STEM education and literacy for the benefit of all students.

Therefore, this study proposes the following research questions:

1. What are the impacts on preservice educators of volunteering at informal STEM events?
2. What are the impacts on families participating in informal STEM events?

These authors will address these questions by collecting data from individual and focus group interviews with preservice teachers and families participating in these informal STEM events. In addition, this study will include data from a reflectional survey preservice teacher volunteers complete after facilitating a station at the STEM events. The authors will inductively analyze this data.

Finally, this research is in its initial stages at this time. We hope that the shared impacts from the preservice teachers and families participating in these informal STEM events will inform the STEM education research community in ways that will promote STEM literacy for all. We also want to share insight gained from families that have participated in the informal STEM events to give them a voice that may be neglected sometimes in STEM education research. Above and beyond this, these STEM learning experiences also provide opportunities for preservice teachers to develop communication skills with children and families before entering the classroom

(Meadows et al., 2020). We hope that by talking to these preservice teachers and the families, we may also gain additional insight into this topic.

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Strength and weakness-based reflection among STEM faculty

Amanda Lake Heath, Sarah K. Bleiler-Baxter, Fonya C. Scott, O. Theresa Ayangbola (Middle Tennessee State University), Olena T. James (Belmont University), Gregory T. Rushton and Grant E. Gardner (Middle Tennessee State University)

Many STEM education scholars are working to understand how to impact university instruction, at the level of the faculty (e.g., Yoshinobu, 2022), graduate student teaching assistant (e.g., Ellis et al., 2019; Reinholz, 2017; Rogers et al., 2020), or through broad departmental change (Reinholz et al., 2020; Smith et al., 2021). In this work, we contribute to and extend this literature by providing an in-depth look into the discourse between university faculty when they are reflecting together upon one another's instruction, attending to the tone and content of their reflections. This research is in direct response to Esterhazy et al. (2021), who provide a call to action encouraging researchers to not only explore what works in collegial faculty development (CFD) but also how it works. In particular, they mention that the field is in need of greater understanding of "the actual interactions and the content of feedback provided during concrete CFD situations" (p. 255). Within this report, we explore the content of feedback provided during Teaching TRIOS debrief sessions, a Time-Sensitive (T), Reciprocal (R), Inclusive (I), Operative (O), and Strength-Based (S) instantiation of CFD that utilizes peer observation and has been used within the mathematics department, and more broadly across various STEM departments, at Middle Tennessee State University (Bleiler-Baxter, Hart, & Wanner, 2021).

Within TRIOS teams, groups of two or three intradepartmental faculty observe one another's instruction and then meet to debrief. The goal is to unpack the strengths of the instructor during that class session. Unlike many traditional forms of peer evaluation, where the observers are positioned as coaches, the TRIOS model is intended to position the instructor as the coach and as an expert in their classroom setting. What we have noticed, though, is that some teams were more effective than others at debriefing in a truly strength-based way, attending to and unpacking the strengths of the instructor rather than identifying weaknesses or offering areas for improvement. We explore two such TRIOS teams, one team of mathematicians that tended toward weakness-based reflection, and one team of biologists that tended toward strength-based reflection. We ask the following research questions:

1. In what ways and upon what content do undergraduate-level STEM faculty reflect within TRIOS debrief sessions that utilize a strength-based approach?
2. In what ways and upon what content do undergraduate-level STEM faculty reflect within TRIOS debrief sessions that utilize a weakness-based approach?

Methods

In this research, we explore the Teaching TRIOS debrief sessions for a biology team (Betty, Bridget, and Brian) and a mathematics team (Margaret and Moby) of university faculty. We selected these two teams to highlight as cases in this manuscript because they illustrate clearly a strength-based approach (biology team) and a weakness-based approach (mathematics team) to debrief discussions, and hence, provide us with insight into our research questions. As this project was conducted during the COVID-19 pandemic, all TRIOS debrief sessions were conducted and recorded via Zoom. Six TRIOS debrief transcripts (three from biology and three from mathematics) were edited, cleaned, and separated into talk turns.

Our data analysis employed two layers of qualitative coding by talk turn. First, we coded each transcript to determine a quantitative description of the use of strength- or weakness-based approaches by each TRIOS team. In a **strength-based reflection**, an asset perspective on instruction is offered, often paired with a genuine interest in learning about instruction. Strength-based reflections are typically educative in nature. In a **weakness-based reflection**, a deficit perspective on instruction is offered, often paired with interest in offering an alternative approach to instruction. Weakness-based reflections are typically evaluative in nature. Two members of the research team independently identified segments from the transcripts that demonstrated a strength or a weakness-based approach.

Then, to compare the levels of reflection present within each TRIOS team, we coded the transcripts through the lens of the Onion Model (Korthagen, 2004). Within this model, reflection can range from the outer, external layers such as reflection upon one's environment, behavior, and competencies to the deeper, core layers such as reflection upon one's beliefs, identity, and mission. Reflection centered on the core levels can create room for deeper introspection and learning (Korthagen & Vasalos, 2005). Two researchers coded each transcript for these six levels of reflection. In order to compare the transcripts, we then scaled the number of codes per category to the total number of Onion Model codes.

Preliminary Results

Strength- and Weakness-Based Reflections

As stated above, we calculated the proportion of codes within a single transcript that demonstrated either a strength- or weakness-based reflection. Confirming our original impression, the biology team largely embraced the strength-based reflection approach to the TRIOS debrief sessions, and although the mathematics team illustrated more weakness-based reflections than strength-based reflections in their first two debriefs, their third debrief demonstrated growth in the use of a strength-based perspective. The aggregate proportions of types of reflections for both the biology team (95.3% strength and 4.7% weakness) and the mathematics team (33.6% strength and 66.4% weakness) led us to consider the biology team as an example of a group using a largely strength-based perspective and the mathematics team as an example of a group using a largely weakness-based perspective

The analysis of the TRIOS debrief transcript revealed a slightly different distribution of levels of reflection present in the biology and mathematics teams' discussions. Although for both teams, the largest area of reflection was behavior and the smallest area of reflection was mission, the strength-based biology team had a higher proportion of reflections regarding their beliefs (18.31%), identity (4.92%), and mission (1.37%) than the weakness-based mathematics team (12.19%, 1%, and 0.5%, respectively). This indicates that it is possible a strength-based perspective may lead to deeper conversations and facilitate a safe environment that facilitates reflection upon the most core features of oneself and one's teaching.

Continued Research Plans

We have currently completed our coding and have explored the quantitative proportions of levels of reflection present in the two teams' debriefs, but we also plan to identify exemplary episodes for each level of reflection and consider the context of how a strength- or weakness- based reflection framed the subsequent conversation. This continued work will qualitatively respond to our hypothesis that focusing faculty feedback on the strengths of the instructor can facilitate a deeper, more vulnerable and positive level of reflection to promote professional development. In the SSERC presentation, we will present the quantitative results of our coding together with qualitative excerpts from our faculty participants.

Acknowledgments

This work was funded through the Tennessee Board of Regents Student Engagement, Retention, and Success Grant 2020-2021 funding cycle.

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Patterns for managing potential conflict between religion and evolution among Muslim undergraduate biology students

Rahmi Qurota Aini (Middle Tennessee State University), Sara Brownell (Arizona State University), and Elizabeth Barnes (Middle Tennessee State University)

Introduction

Evolution is a foundational component of biology (AAAS, 2011), yet it is controversial in the public and among biology students (Sbeglia & Nehm, 2018, 2019). The perceived conflict between religion and evolution is the most predictive factor for whether a student will reject evolution (Barnes et al., 2021), and perceived conflict between religion and evolution also varies depending on religious affiliation. A nationwide study conducted indicated that Muslim and Christian biology students had the lowest acceptance of evolution compared to Jewish, Hindu, and Buddhist students (Barnes et al., 2021). To understand the low acceptance rates of evolution among biology students, an abundance of research has been conducted on undergraduate biology Christian student populations in the United States (Bradshaw et al., 2018; Martin, 2010) but very few research studies have explored Muslim student perceptions in the United States beyond their levels of evolution acceptance. In this study, we specifically examined how undergraduate biology Muslim students in the United States manage potential conflict between evolution and their religion.

Methods

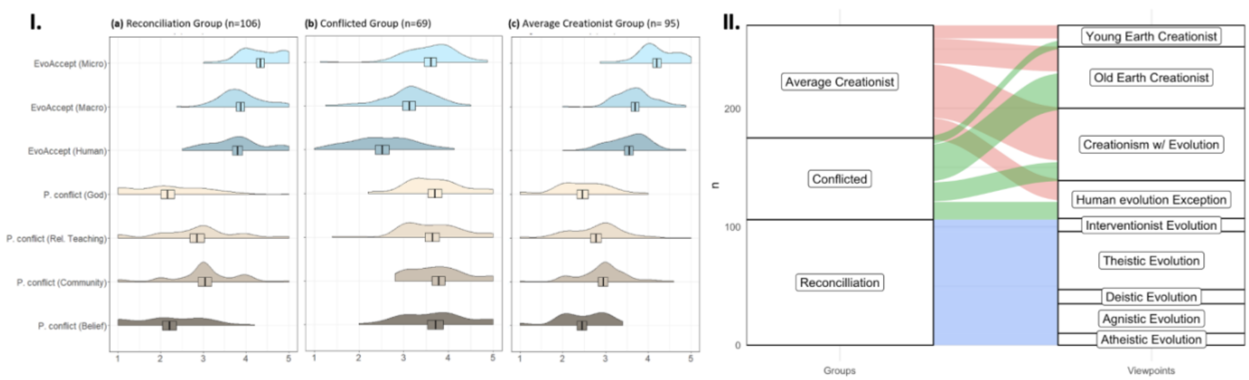
From fall 2018 to spring 2021, we collected survey data from undergraduate students enrolled in introductory biology courses across 14 states in the United States. 270 students who identified as Muslim and completed all survey questions were selected for this research. Students filled out previously published surveys measuring their levels of evolution acceptance and their perceived conflict between their religion and evolution. Students also chose their view on the relationship between creationism and evolution from 9 options that spanned special creationism, theistic evolution, and atheistic evolution and were then asked to explain why they chose their specific answers.

We used k-means cluster analysis to understand patterns based on students' acceptance of evolution and their perceived conflict between their religion and evolution. Furthermore, students' open-ended responses were coded using a previously constructed framework to examine views on the relationship between evolution and religion. First, we categorized students' responses to accepting evolution and religion as reflecting primarily compatibility or incompatibility views (Cohen's kappa = 0.73). We then used a previously constructed framework to deductively categorize students' views on the relationship between evolution and religion (Yasri et al., 2013) (Cohen's kappa = 0.66). Inductive coding was then used to determine any themes not captured by the primary framework (Cohen's kappa = 0.80).

Findings

Three clusters of students best described the data. Figure 1 presents the group characteristics based on their mean scores on evolution acceptance and perceived conflict between evolution and religion.

Figure I: The distribution and average of scores of undergraduate Muslim biology students on evolution acceptance and perceived conflict between evolution and religion by cluster. Reconciliation Group (a) had the highest evolution acceptance and the lowest perceived conflict between evolution and religion. Conflicted group (b) had the lowest acceptance of evolution compared and the highest level of perceived conflict between evolution and religion. Average Creationist Group (c) had average scores that are closest to the mean on all variables across groups. Figure II: Distribution of students' views on evolution and creationism based on their group.



The majority of students in The Reconciliation Group, 91% (n=69/76), perceived evolution and religion as Compatible. None of the students in this group chose special creationist views that were incompatible with evolution. 30% of these students' open-ended responses were categorized as showing a Consonance relationship between religion and evolution (n=30/76). This refers to the idea that students perceived the combination of evolution and religion as two sets of knowledge that are necessary to provide complete explanations. The Conflicted Group consisted of 25% of Muslim students (n = 69/270) who had the lowest evolution acceptance and highest perceived conflict between their religious beliefs and evolution. None of the students in this group chose views compatible with evolution. 91% of this group (n=41/45) were coded as primarily perceiving incompatibility between religion and evolution. The last cluster, The Average Creationist Group consisted of 35% of students (n=95/270) who had an average evolution acceptance and average perceived conflict between their religious beliefs and evolution compared to other Muslim students. None of the students in this group had views compatible with evolution. In this group, 97% of students (n=57/59) primarily saw Incompatibility between accepting evolution and religion, and 34% (n = 20/59) were coded as believing Religion Trumps Science.

General Discussion and Implications

Although students were affiliated with the same religious belief, this research indicated that undergraduate Muslim students have dynamic and complicated ways of managing potential conflict between evolution and religion. Interestingly, Muslim students who had average evolution acceptance scores often held special creationist views that were incompatible with evolution. This group described seeing some compatibility between evolution and religion even though they reject the idea that all forms of life evolved. This is important for understanding the growing population of Muslim biology students in the United States and how to teach evolution in a way that is inclusive of their religious background and minimize potential conflict.

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Undergraduate science communication about culturally controversial science topics: The role of politics, religion, and race

Elizabeth Barnes (Middle Tennessee State University)

Background and Significance

Developing undergraduate students' science communication skills has been described as important by influential reports across science disciplines including biology, chemistry, and physics. Yet, there is little research on effective ways to teach undergraduate science students how to communicate about some of the most important and yet controversial science issues in society like climate change and vaccines. I have called these issues **Culturally Controversial Science Topics (CCSTs)** due to their controversial nature within society and yet widespread acceptance among experts. Current scientists and science educators have failed to prevent or reduce political polarization about CCSTs, and this could be because communicating about contentious topics is not a formal part of a scientist's training. As a response, my research group has begun to build a research program to identify ways to increase undergraduate students' ability to communicate effectively about CCSTs to their friends and family. In this talk, I will give an overview of the first three studies we conducted to build this research program on undergraduate CCST communication.

Research Questions

To create scalable instruction that can increase students' CCST communication skills I needed to first understand student experiences and conceptions about CCST communication. So, my research team conducted three studies to characterize students' current CCST communication experiences and knowledge. We asked the following research questions:

Study 1: To what extent did biology students serve as science communicators about COVID19 and COVID19 vaccines during the pandemic? How confident did they feel communicating? Did they use effective science communication principles? Was religious affiliation, political affiliation, and race associate with students' experiences and knowledge?

Study 2: How often do undergraduate students communicate about climate change within their communities? How confident do they feel communicating? Do they use effective science communication principles when they are communicating with others?

Study 3: How do students from Black communities conceptualize their role as science communicators within their communities? How did they experience communicating about COVID19 and COVID19 vaccines during the pandemic? What instruction do they believe would have helped them increase their confidence and effectiveness communicating?

Methods & Analyses

We surveyed 533 undergraduate biology students at a southeastern university to learn about their experiences and knowledge communicating about COVID19 vaccines. To learn specifically about the experiences of students from Black communities, my research team interviewed 23 Black biology students about their experiences communicating about COVID19 vaccines within their community. Finally, to learn about student experiences communicating about another CCST beyond COVID 19 vaccines, we surveyed 255 undergraduate biology students at 38 different institutions about their communication frequency and confidence communicating about climate change. We subsequently interviewed 32 of the surveyed students to explore their experiences in more detail. For each study, we ran descriptive statistics on closed ended survey data and conducted inductive and deductive coding on qualitative data. Further, for study one, we conducted regression analyses to determine if student communication variables were related to their political, religious, or racial/ethnic identification.

Summary of Findings

Students were communicating about CCSTs often but were not using many effective science communication principles. 79% of undergraduate biology students reported talking about climate change with others outside of class once per month or more and students were communicating frequently about COVID19 vaccines at a crucial time when the vaccines first became available to the public. Many of these students had misconceptions about COVID19 vaccines that are commonly seen in the southeastern United States including a perception that the vaccines are unsafe. Students who were politically conservative, religious, and identified as Black were more likely to have misconceptions and yet were just as likely to be communicating about COVID19 vaccines within their communities.

We interviewed 32 students from our nationwide sample about how they were communicating about climate change, and we asked our 533 students in the southeast to write about what they would say to someone who did not want to receive a COVID19 vaccine. These studies were the first to identify students were unaware of most strategies experts recommend for communicating about CCSTs. Further, many students reported using potentially ineffective strategies such as berating or avoiding people with different views from them. Among both populations of students, the most prevalent communication strategy cited was giving facts to other people about the science to help them “understand better” despite ample evidence that suggests factual understanding alone is often unrelated to people’s opinions about socially charged topics[9–11]. Very few students mentioned positive strategies reflective of science communication principles such as creating dialogue, showing respect, and listening to the individual’s viewpoint to better understand their concerns. Both populations of students also described experiencing negative emotions such as anger and frustration during their conversations, which caused a cognitive load that made it difficult to be an effective and empathetic communicator.

When we interviewed biology students who are part of the Black community, we found similar findings as the first two studies: Black students mostly said they told people “Facts” about the COVID19 vaccines to communicate and expressed a concern that they did not know how to communicate effectively. In this study however, almost all students had come to trust and adopt COVID19 vaccines as safe and effective and most of these students recognized their potential importance as a trusted messenger within the Black community in which there is hesitancy due to historical and modern racism. Many students said they felt a responsibility as a Black person and a science person to adopt that role effectively. So, while students were serving this role within their community, these results indicated they may need more support to learn how to communicate effectively.

Collectively, these three studies revealed that undergraduate biology students are already science communicators about CCSTs within religious, politically conservative, and Black communities. However, students often use ineffective strategies identified in the science communication literature as a “deficit approach” to science communication. Scientists who take this approach believe that if they were to expose people to evidence or facts that this alone would influence the person to have conceptions more in line with the evidence. However, many studies and experts have revealed that without addressing the emotions and values associated with the topic, communication is unlikely to impact someone’s views [10,11,21]. These studies reveal a need to teach science students about the deficit approach and to introduce them to more effective communication habits such as creating a dialogue to understand the other person’s point of view, finding areas of agreement and shared values, and approaching the conversation with respect and curiosity. Future research from our group will aim to create lesson plans and videos to help reduce the deficit approach to science communication among undergraduate biology students.

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Elevating student voices to catalyze system change in STEM education

Yoi Tibbetts and Chris Hulleman (University of Virginia)

If a goal of the United States' higher education system is to enroll and graduate more Black, Indigenous, and people of color (BIPOC) in the fields of Science, Technology, Engineering, and Mathematics (STEM), it is imperative that their voices are fully integrated into future reform efforts. Because the U.S. higher education system was constructed with an emphasis on norms of expressive individualism, prevalent among a White middle class (e.g., Stephens et al., 2012), students who are not socialized with these agentic values (e.g., BIPOC and first-generation college students) can experience college as "not for me," resulting in elevated levels of belonging uncertainty (e.g., Harackiewicz et al., 2016). Further "othering" of these students stems from the additional barriers of negative stereotypes and discrimination (e.g., Grossman & Porche, 2014), resulting in additional messages of non-belonging that carry critical implications for student success (Walton & Brady, 2017). Nascent models of system reform suggest that elevating the voices of historically under- heard populations is a critical first step towards supporting their growth and development (Caraballo et. al., 2017).

The Student Voices Initiative arose out of an ongoing five-year partnership between the Tennessee Board of Regents (TBR) and the University of Virginia (UVA). The Student Voices Initiative uses a youth participatory action research approach, which engages students at every level of the research process, which includes evidence-based focus groups, coding protocols, and system-change supports intended to both support current students and enable institutions to implement systemic improvements for the benefit of future students. This research model allows instructors and administrators to better position themselves to listen to and learn directly from their students. Given our specific desire to improve belonging across two fronts: both by supporting individual students via their focus group participation, and by highlighting opportunity structures for institutions to leverage, we developed a logic model that explicates how operating at both the student and institutional level can support BIPOC students.

At the student level, and consistent with other discussion-based belonging interventions (e.g., Binning et al., 2020), we hypothesized that belonging-centered focus groups will increase student belonging, thereby leading to greater academic performance. Prior research has shown that targeting belonging can lead to improved STEM outcomes (e.g., increased STEM grades, particularly among students historically marginalized by STEM disciplines; Binning et al, 2020; Walton et al., 2015), which previously has demonstrated the power to increase longer-term STEM outcomes like retention (Canning et al., 2018; Hecht et al., 2019). At the institution level, we hypothesized that focus group coding protocols that identify opportunity structures will highlight opportunities that can lead to actionable recommendations. The research questions were:

1. Does utilizing our focus group protocol increase student belonging, leading to improved STEM outcomes, particularly for students from traditionally underserved backgrounds?

2. Does utilizing our focus group protocol and system-change supports enable institutions to identify salient opportunity structures that can be targeted with belonging supports?

3. What are effective strategies for supporting institutions to elevate and incorporate BIPOC student voices into their system-change efforts?

Belonging Uncertainty at TBR.

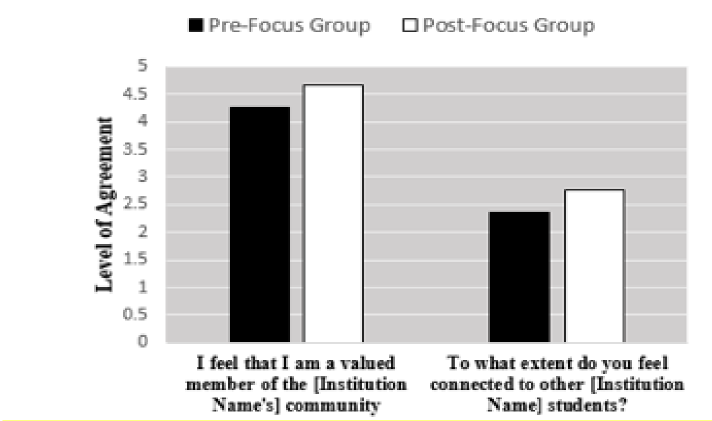
Data-collection efforts at TBR, revealed that traditionally underserved students report increased feelings of belonging uncertainty across TBR's 13 community colleges. In an annual "Getting to Know Your Students" survey, the Fall 2018 and Fall 2019 first-year student cohorts (over 5,000 students each year) at Tennessee community colleges reported their feelings of belonging uncertainty (Walton & Cohen, 2011; "Sometimes I feel like I belong at college, and sometimes I feel that I don't belong at college"; 1-6 Likert scale) at two time points—once at the beginning and once at the end of the semester ($\alpha1= 0.73$, $\alpha2= 0.75$). Overall, students reported a modest increase in belonging uncertainty between Time 1 and Time 2 ($M= 0.13$, $SD= 1.34$, $n= 674$). However, Black students reported disproportionately larger increases in belonging uncertainty ($M= 0.43$, $SD= 1.51$) compared to their White ($M= 0.09$, $SD= 1.29$, $n=488$) peers. Critically, students' reported change in belonging uncertainty was negatively related to their overall semester GPA ($\beta= -0.20$, $p< 0.001$), even when controlling for student characteristics such as race/ethnicity, gender, generational status, and prior achievement (operationalized here as high school GPA). That is, students who experienced more belonging uncertainty over the course of the semester (as was the case, on average, for Black students) earned a lower semester GPA.

To combat the negative effects of the increased belonging uncertainty plaguing students, the team conducted pilot studies with 868 first-year students across 5 TBR institutions over 3semesters (Spring 2020, Fall 2020, and Spring 2021). A subset of the data from these three semesters of focus groups have been coded and analyzed ($n= 541$). Students at each institution participated in peer-facilitated focus groups and discussed what helped and hindered their sense of belonging. The most compelling reason for training student facilitators to lead focus groups is that students are more likely to speak up and talk openly about feelings of (non-)belonging with their peers than with researchers, faculty, or staff.

After creating both face-to-face and virtual focus group protocols, we then developed a coding protocol to capture the opportunity structures that play a role in student belonging and contribute to existing equity gaps. Other important opportunity structures highlighted by our preliminary analyses were university resources and policies (27.0% helped; 32.5% hindered), as well as interactions with peers in student-facilitated groups and clubs (20.9% helped; 19.0% hindered). Additionally, for a subset of focus group participants, we examined students' sense of belonging before and after attending focus groups. Results indicated that participating in student-led focus groups resulted in students feeling like more valued members of their school community (Cohen's $d= .31$) and more connected to their peers (Cohen's $d= .40$). Together, these findings speak to the potential of The Student Voices Initiative to positively impact students' sense of belonging in community colleges on two ends. Firstly, merely participating in focus groups could increase students' sense of belonging. Secondly, by elevating student voices we shed light on a variety of opportunity structures that help or hinder students' sense of belonging, which has important implications for policy and practice.

Given that belonging has consistently been shown to be a significant predictor of academic success (e.g., Walton & Brady, 2017), educators and policymakers need to identify the undergirding systemic factors that contribute to the belonging uncertainty experienced by many BIPOC students. Failure to address these belonging concerns will continue to lead to inequities in STEM fields. Fortunately, prior student-centered interventions addressing belonging uncertainty have shown the potential to support BIPOC students' short- term (e.g., GPA; Walton & Cohen, 2007) and long-term (e.g., psychological well-being years after intervention implementation; Brady et al., 2020) outcomes. This has led to a proliferation of belonging interventions that focus on targeting individual students with specific intervention materials designed to help them overcome their own belonging uncertainty (e.g., Broda et al., 2018; Paunesku et al., 2015). Although these effects are promising, we argue that a more sustainable approach would come from implementing systemic change designed intentionally to increase institutions' accountability in removing structural barriers that hinder the belonging of BIPOC students in STEM disciplines. To do so, it is critical that institutions listen to these students and learn from their experiences.

Figure 1. Students' perceived value and connection pre- and post- focus group



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Faculty reflections on inclusive pedagogy within STEM classrooms

O. Theresa Ayangbola, Fonya C. Scott, Sarah K. Bleiler-Baxter (Middle Tennessee State University), Olena T. James (Belmont University), Amanda Lake Heath, Grant E. Gardner, and Gregory T. Rushton (Middle Tennessee State University)

US universities are becoming more demographically diverse, but this has yet to be reflected in STEM disciplines. National calls to mitigate the attrition rate for underrepresented minorities (URMs) in STEM suggest that faculty must be equipped to teach diverse students (Austin, 2011). Inclusive classroom environments and instructional activities successfully reduce attrition (Kuh et al., 2011). However, higher education institutions must offer opportunities for faculty to engage in professional development to become more knowledgeable in inclusive pedagogy. In response to significant differences between the retention of URM students and students from other ethnicities in STEM, faculty development of inclusive teaching practices has become more common (Dewsburry, 2017).

There has been little scholarship examining the impacts of STEM faculty professional development on inclusive practices. We study a specific example of a faculty learning community using the Teaching TRIOS peer observation process (Bleiler-Baxter, Hart, & Wanner, 2021). As STEM faculty participated in a professional development aimed at supporting their awareness and responsiveness to varied backgrounds, learning styles, and cultures of learners in their STEM courses, we sought to understand the following research questions:

(1) In their reflections on inclusive pedagogy during the Teaching TRIOS debrief sessions, what do STEM faculty participants prioritize?
(2) When instructors discuss the most prioritized aspects of inclusivity, how do they reflect on their practices?

Data Collection and Analysis

This study is a part of a more extensive qualitative case study about implementing a year-long professional development (PD) program in inclusive pedagogy among STEM faculty. Nine STEM faculty, three each from chemistry, biology, and mathematics, participated in the PD. This study focuses on phase two of the PD- Teaching TRIOS. Teaching TRIOS is a peer observation model whereby teams of three engage in a three-part iterative process of observing, reflecting, and debriefing one another's classroom practice (Bleiler-Baxter, Hart, & Wanner, 2021). The goal of the debrief sessions was to unpack the strengths of the observed instructor, each session lasting for about fifty minutes. All TRIOS debrief sessions were recorded on Zoom and transcribed verbatim through the transcript software, Otter.ai (2021). To answer our research questions, the TRIOS debrief sessions of the biology group were analyzed because they implemented the Teaching TRIOS process with the most fidelity. This group consisted of a white male full professor, a white female assistant professor, and a white female instructional faculty. Their pseudonyms are Dr. Alvin, Dr. Cathy, and Dr. Bella.

Analytical Framework: We used the Conceptions of Diversity in Higher Education Framework (Suarez et al., 2021). The framework explores how instructors perceive the role of diversity in their teaching and their student's learning. We focused on the five aspects from the framework, which include, (a) Student Identities- describes how an instructor interprets the characteristics that make students diverse, (b) Intelligence Mindset- describes how an instructor perceives student intelligence, (c) Student Engagement- describes how an instructor perceives the impact student diversity has on student engagement, (d) Instructor Action- describes how an instructor perceives their role in teaching students from diverse backgrounds, and (e) Legitimized Membership- describes how an instructor positions students relative to implicit classroom norms and structures.

Findings

RQ 1: In their reflections on inclusive pedagogy, what do STEM faculty participants prioritize?

To answer our first question, we identified the most commonly reflected-upon aspects of the framework. Across all three debrief sessions, we found that participants focused primarily on instructor actions and legitimized membership (see Table 1). The least prioritized aspects were student identities, intelligence mindset, and student engagement.

Table 1: Summary analysis using the Conceptions of Diversity Framework

	Total number of talk units coded	Student Identities	Intelligence Mindset	Student Engagement	Instructor Actions	Legitimized Membership
Debrief Session 1	180	1 (1%)	0	6 (3%)	19 (11%)	10 (6%)
Debrief Session 2	200	2 (1%)	0	0	18 (9%)	13 (7%)
Debrief Session 3	205	2 (1%)	5 (2%)	0	19 (9%)	11 (5%)

Participants' reflections prioritized instructor actions and legitimized membership, which can be attributed to debrief sessions that unpacked faculty instructional practices. Student identities, intelligence mindset, and student engagement were the least prioritized aspects of the framework; these are more internal to the participants, making them more challenging to access and observe.

RQ 2: When instructors discuss the most prioritized aspects of inclusivity, how do they reflect on their practices?

For our second research question, we identified talk turns with codes of instructor actions and legitimized membership. Then, we conducted inductive coding to uncover common themes within those two broad categories. We found that the TRIOS participants reflected on two broad themes of instructor actions and ways they position students for legitimized membership in their STEM classrooms: (1) use of engaging pedagogy and (2) caring disposition. The themes are defined as follows.

Use of Engaging Pedagogy: Engaging pedagogy is conceptualized as practices enacted by instructors that ensure participation for all students, e.g., having clear expectations.

Caring Disposition: Caring disposition is conceptualized as an indication of concern for their students' needs.

Faculty often reflected on how their action of using engaging pedagogy fosters a safe space for students. For example, faculty stated examples of inclusive instructional practices enacted in their classroom. Dr. Alvin had a clear expectation of attendance on his syllabus, and Dr. Cathy used learning objectives in her class.

In the SSERC presentation, we will describe the patterns of reflection detected as TRIOS participants unpacked the strengths of the observed instructor and considered how their approaches inform inclusive STEM instruction.

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Who am I?

Lisa Salvato (Tennessee Technological University)

Abstract

The U.S. Department of Education's Individuals with Disabilities Education Act (IDEA) website (2022) states that IDEA "is a law that makes available a free appropriate public education to eligible children with disabilities throughout the nation and ensures special education and related services to those children" (About IDEA, para.1). The primary goal of special education in the United States is to give students with disabilities an optimal learning experience (Cook & Schirmer, 2003). According to a 2019 National Science Foundation report, individuals with disabilities are underrepresented in STEM fields and have a higher rate of unemployment (Hamrick, 2021). STEM educators need to know best practices in STEM education to optimize the learning experience of students with special needs as well as what prevents their participation (Klimaitis & Mullen, 2021).

Development of a STEM identity may influence students' decision-making concerning course enrollment, college majors, and career choices (Godwin, Cribbs, & Kayumova, 2020). STEM identity determines whether one believes they can be successful or make contributions to STEM (Bell et al., 2018). Beliefs of teachers, parents, peers, and society about STEM all contribute to the development of a STEM identity and help students to answer the question, "Who am I?"

This content analysis looked at 334 articles from five STEM education research journals published between January 2018 and December 2021 (four years) to determine the scope of research related to the inclusion of students with special needs in STEM and promoting their STEM identity. Six research questions were asked.

1. How many articles (scope of research) were devoted to STEM education for students with special needs?
2. How many articles were focused on understanding the role of identity in STEM education?
3. How many articles were focused on understanding equity in STEM education?
4. What theoretical perspectives in STEM education were being applied to improving science instruction for students with special needs?
5. Where was STEM education research being conducted geographically?
6. Who were the participants (students, teachers, both, and/or, other) in STEM education research studies?

There is limited research on including students with disabilities in STEM. The significance of this study is in its focus on recent research in STEM education related to the inclusion of students with special needs in STEM and fostering their development of a STEM identity.

Five STEM education journals were selected, and all the published research articles therein were coded and analyzed for the purpose of this study. Results indicated that those with special needs are often underrepresented in STEM education research. Of 334 STEM education research articles, only six discussed special education. Autism, cognitive disability, deaf/blind, gifted

students, dyslexia and learning disabilities were discussed in these six articles. It is noteworthy that all the studies pertaining to special education in STEM education research were conducted internationally.

Keywords: disabilities, special education, STEM, identity, inclusion

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POSTER PRESENTATIONS

AUTHORS AND ABSTRACTS

S²ERC

SOUTHEASTERN STEM EDUCATION RESEARCH CONFERENCE

2023

A new survey of perceived conflict between evolution and religion reveals differences in atheist and Christian biology students' perceived conflict between religion and evolution

Katie Coscia (Middle Tennessee State University), Sara Brownell (Arizona State University), and Elizabeth Barnes (Middle Tennessee State University)

Background: Evolution is one of the core theories in biology that unifies concepts across all disciplines (American Association for the Advancement of Science (AAAS), 2009; Brownell et al., 2014). Despite its foundational nature, the theory of evolution remains controversial and much of society, including students in the biological sciences, are hesitant to accept it. There is a common notion that evolution and religion are mutually exclusive and that one must forsake their belief in God to accept evolution (Barnes et al., 2020). Both religious and non-religious students have this conception, indicating that they both perceive a conflict between religion and evolution. However, no one has explored the level of perceived conflict between religion and evolution among non-religious students.

Significance: If non-religious students perceive high conflict between religion and evolution, this could impact the way they communicate about evolution to their religious peers and future students (Barnes et al., 2017; Barnes & Brownell, 2016) and ultimately influence their future peers and students' levels of evolution acceptance.

Research Question: To what extent do non-religious and religious college biology students perceive conflict between religion and evolution?

Methods and Analysis: We used a survey to gather data from 11,537 students (Table 1) in introductory biology classes in 14 states. We measured students' perceived conflict between religion and evolution with our newly developed survey and gathered students' religious affiliations. We used ANOVA with post hoc comparisons to explore whether there were differences in perceived conflict between students from different religious affiliations.

Table 1. Religious affiliation of students surveyed. All students were enrolled in introductory biology courses at colleges and universities across 14 states.

religious affiliation

		Frequency	Percent
Valid	atheist	1262	10.5
	agnostic	2026	16.9
	Protestant	1887	15.7
	CJCLDS	790	6.6
	nondenominational	1007	8.4
	Catholic	2468	20.6
	Jewish	205	1.7
	Muslim	313	2.6
	Hindu	234	2.0
	Buddhist	257	2.1
	other religion	1088	9.1
	Total	11537	96.2

Summary of Findings: Students across religious affiliations tended to have moderate levels of perceived conflict between religion and evolution. A one-way ANOVA showed that there was a statistically significant difference in perceived conflict between religious and non-religious groups. LSD post hoc analyses revealed that atheist students had significantly less perceived conflict than all other groups examined except for Buddhist students ($p < 0.1$), while students within the Church of Jesus Christ of Latter-day Saints perceived the highest amount of conflict (Figure 1). All differences between groups were small.

These results suggest that non-religious students perceive slightly less conflict between religion and evolution than students from all religious affiliations. Further, Christian biology students harbor some of the highest perceived conflict between religion and evolution. Although students from all groups tended to perceive moderate conflict, these results, along with other studies, further highlight the need for instructors to use Religious Cultural Competence in Evolution Education (ReCCEE) to help students see potential compatibility between religion and evolution.

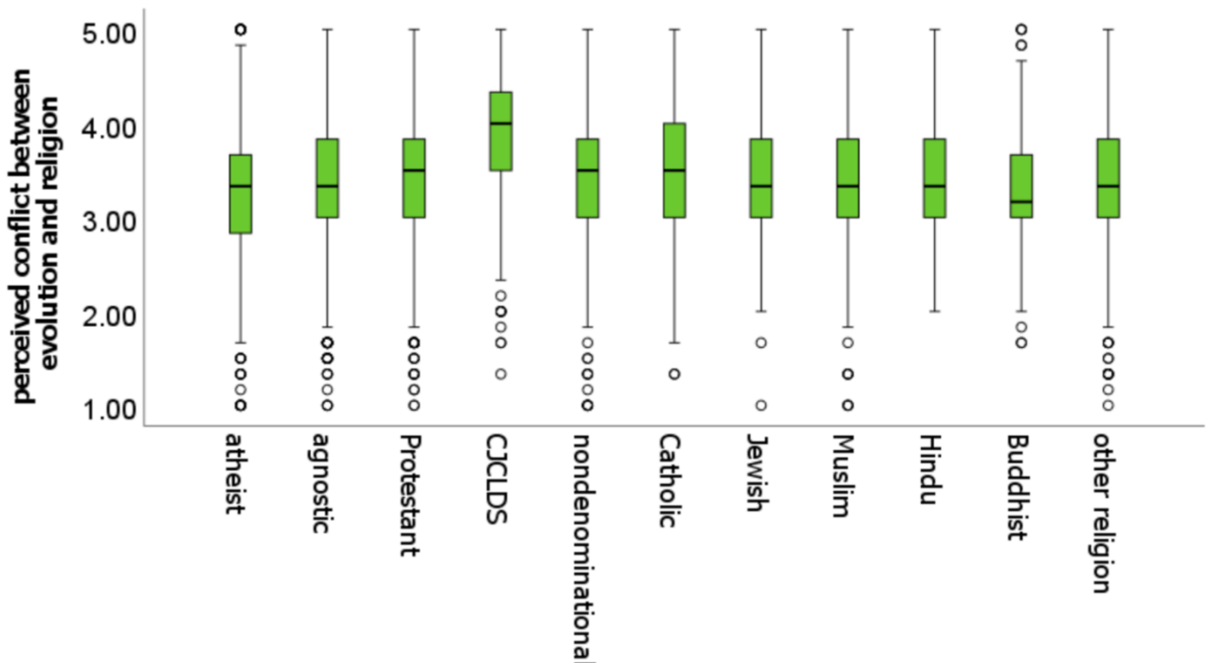

Figure 1. Mean perceived conflict between religion and evolution of all students surveyed separated by religious group. Questions were on a 5-point Likert scale. 5 indicates the highest degree of perceived conflict.

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An experimental study testing the effect of biology instructor identity on reducing students' perceived conflict between evolution and religion

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

Background and Significance: Though evolution is a core cncept of biology, many undergraduate biology students still reject it (AAAS, 2011; Brownell et al., 2014). There are several factors that could influence people's acceptance of evolution, but one that has been of particular interest recently is students' perceived conflict between religion and evolution (Barnes et al., 2021; Rissler et al., 2014). Perceived conflict has been shown to be a stronger predictor of students' acceptance of evolution than evolution understanding or religiosity. While the public and many biologists are religiously affiliated, there still exists a bias among the biology community against religion which can result in nonculturally competent instruction for Christian students (Jackson et al., 1995). The inability of some professors to respect or empathize with students' ranging religious views is only more likely to perpetuate students' perceived conflict between evolution and religion.

As a bridge to the religious cultural gap in evolution instruction, religious cultural competence in evolution education (ReCCEE) has been recommended and shown to help secular instructors decrease students' perceived conflict between evolution and their religious beliefs (Barnes & Brownell, 2017). For instance, when a secular instructor provides religious scientist role models who accept evolution and discusses the nature of science as being agnostic rather than atheistic this can decrease students' perceived conflict (Truong et al., 2018). However, other studies have shown that integrating religious instructors who discuss ways that they see evolution and religion as reconcilable can effectively increase students' acceptance of evolution (Ferguson & Jensen, 2021). Thus far no one has tested if the religious identity of the instructor differentially impacts the effectiveness of instruction meant to reduce students' perceived conflict between religion and evolution. Further, studies implementing the potential compatibility of religion and evolution still lack control groups to test the efficacy of these practices.

In this study, we used a randomized control trial experimental design to test the effectiveness of instructional videos meant to reduce students' perceived conflict between religion and evolution coming from an instructor who discloses a Christian identity or a secular identity compared to a control group who only receives evidence for evolution in which the instructor does not discuss their religious identity.

Research Questions: How does the religious identity of an instructor and student influence the impact of instruction on reducing students' perceived conflict between evolution and religion?

Methods and Analyses

We surveyed students on their perceived conflict between religion and evolution before and after they were randomly assigned to watch one of three videos. One group watched a 15- minute lecture video with only an introduction to evolution and evidence for evolution but did not receive any instruction highlighting potential compatibility between religion and evolution (control condition). The two intervention groups received the same 15-minute video with additional instruction from the instructor who revealed themselves as either secular (ReCCEE condition) or Christian (Reconciliation condition) and described the potential compatibility between religion and evolution (Figure 1).

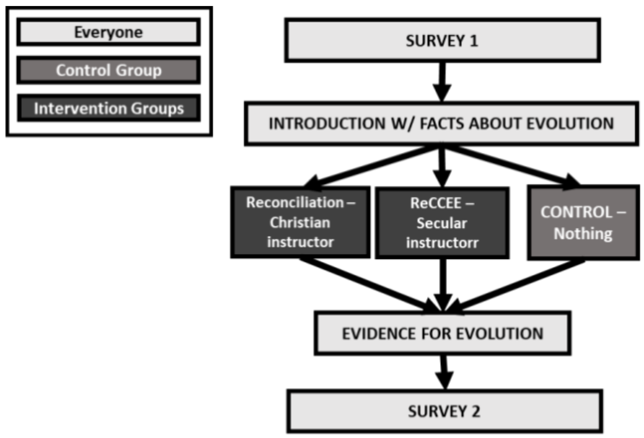

Figure 1: Illustration of study design.

1,133 introductory biology students participated in this study. Before students watched videos, we surveyed student religiosity, religious affiliation, and their level of perceived conflict between evolution and religion. Students filled out a 6-item survey to measure if they perceived conflict between evolution and religion in general (Example item: "Scientists and religious people cannot see eye to eye about evolution"). Only the students who identified with a religious affiliation filled out an additional 5-item survey to measure if they perceived conflict between evolution and their religious belief (Example item: "My personal religious beliefs make it harder to believe that all of life on Earth evolved from ancient microscopic life"). Then, students were randomly assigned to either the control, ReCCEE, or reconciliation group. After watching the video, we measured again their perceived conflict between evolution and religion. We used linear regression models with interactions to test which conditions were most effective for students from different religious backgrounds for reducing their perceived conflict between evolution and religion.

Findings and Conclusion

When we included all students in the model, students' perceived conflict between evolution and religion was predicted to decrease in reconciliation and ReCCEE conditions compared to the control condition. This indicates that instructor identity does not influence the effectiveness of religious cultural competence to reduce students' perceived conflict between evolution and religion, and that practicing religious cultural competence was more effective than just giving evidence for evolution during the lecture. We also found that more religious students were more likely to increase perceived conflict between evolution and religion. Accounting for students' and instructors' identities, the reconciliation condition in which the instructor revealed themselves as Christian was more likely to decrease the perceived conflict of students who scored higher on the religiosity measure, while the ReCCEE condition in which the instructor identified as secular was more effective for reducing perceived conflict between evolution and religion for agnostic and atheist students compared to Christian students.

The results highlight not only the importance of religious cultural competence practices for religious students, but also how instructors' own religious identities can facilitate decreasing students' perceived conflict between evolution and religion. Decreasing the stigma surrounding Christian instructors in biology may help these instructors feel more comfortable revealing their religious identity to students would in turn help reduce their perceived conflict with evolution. However, this study also found that secular instructors are more effective for reducing perceived conflict between evolution and religion among secular students who may go on to become biologists and biology teachers. This illustrates the role secular instructors can take in reducing perceived conflict by implementing religious cultural competence when they teach evolution.

Table 1. Participants demographic information

Religion	**Frequency**	**Gender**		**Race/Ethnicity**	
Christian	588 (52%)	Woman	772 (68%)	Asian	181 (16%)
Agnostic	232 (20%)	Man	335 (30%)	Black	72 (6.4%)
Atheist	93 (8.20%)	Nonbinary	13 (1.10%)	Islander	3 (0.30%)
Oter	220 (19%)	Other	6 (0.50%)	Latinx	175 (15%)
		Decline to state	7 (0.60%)	Native	6 (0.05%)
				White	613 (54%)
				Decline to state	25 (2.20%)
				Other	58 (5.20%)
				Total	1,133

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Undergraduate biology students show patterns of identity protective cognition and motivated reasoning about evolution

Madison Stewart, Elizabeth Barnes (Middle Tennessee State University), and Sara Brownell (Arizona State University)

Background and Significance:

Even though evolution is one of the five core concepts of biology, it remains controversial in American society and among college biology students (Barnes et al., 2020; Gallup, 2019). Prior studies show patterns of motivated directional reasoning and identity protective cognition among the public about their views on evolution (Weisberg et al., 2018) but research has not yet explored if these patterns exist among undergraduate biology students.

Motivated reasoning and identity protective cognition occur when someone reasons towards a conclusion based on their ideology or social group (Kahan, 2017; Kunda, 1990) rather than based on accuracy goals which are more in line with scientific thinking. These reasoning patterns have led to political and religious polarization about topics for which there is clear scientific consensus such as the causes of climate change, the safety and effectiveness of vaccines, and the evolution of life on Earth. These patterns among the public are concerning, but we may also see these patterns among undergraduate biology students. In this study, we explored patterns of motivated reasoning and identity protective cognition among undergraduate biology students about evolution. If patterns of motivated reasoning are detected, this implies a need to implement instruction that will increase accuracy-oriented reasoning about culturally controversial topics taught in undergraduate biology.

Evolution is an ideal topic in which to study motivated reasoning because the evidence for evolution is incredibly strong and yet is often rejected based on perceived conflicts with religious culture and beliefs (Barnes et al., 2021). This leads to classic patterns of motivated reasoning in which those with low religious commitment are much more likely to accept evolution when they have a good understanding of evolution, but those with high religious commitment do not show this same pattern. A good understanding of evolution is not as strong of a predictor of evolution acceptance among highly religious American populations (Weisberg et al., 2018). However, no one thus far has examined whether this relationship changes based on the context of evolution. If motivated reasoning based on religious identity is occurring among undergraduate biology students, we would expect to see stronger patterns of motivated reasoning when examining their reasoning about constructs most likely to conflict with religious belief and culture such as human evolution.

Research Questions:

1. Are there patterns of motivated reasoning among undergraduate biology students about evolution based on their religious identity?

2. Do these patterns change based on the context of evolution such as microevolution, macroevolution, and human evolution?

Methods and Analyses

We surveyed 11,988 students in 48 introductory biology courses about their evolution acceptance (Nadelson & Southerland, 2012), evolution understanding (Short & Hawley, 2012), and religiosity (commitment to religion) (Cohen et al., 2008) in 14 states. To detect patterns of motivated reasoning, we conducted linear regressions with interaction terms testing for differential relationships between evolution acceptance and understanding among students with different religiosity levels. If motivated reasoning is present, the interaction effects in our model would be statistically significant. We also looked at R values from simple slope analyses of students from low religiosity, moderate religiosity, and high religiosity groups to see if understanding of evolution explained a different amount of variance in the evolution acceptance of students from different religiosity groups.

Results:

We found significant interactions between evolution understanding and religiosity for macroevolution acceptance ($p <. 05$) and human evolution acceptance ($p< .05$) but not microevolution acceptance ($p = .085$). Evolution understanding was a strong predictor of microevolution acceptance for students of all religiosity levels (see Figure 1a) but was only a strong predictor of macroevolution and human evolution acceptance for low religiosity students (see Figure 1b-c). These findings suggest patterns of motivated reasoning among religious and highly religious students. Future research could explore how teaching students about motivated reasoning, reducing perceived conflict with religious identity, and increasing accuracy-oriented goals could help mitigate the patterns of motivated reasoning detected in this study.

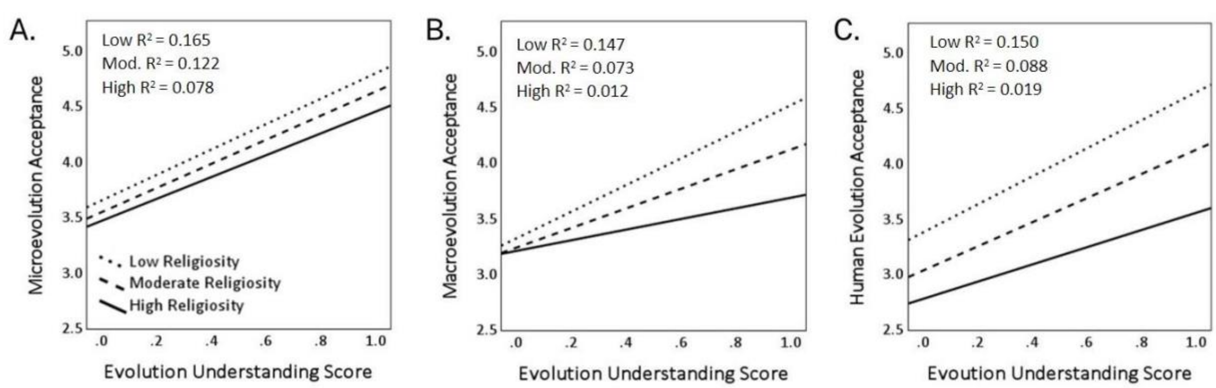

Figure 1: Linear regression analyses show interactions between student understanding of evolution and student religiosity levels for (A) microevolution acceptance (B) macroevolution acceptance and (C) human evolution acceptance. R values are from simple slope analyses.

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Assessing validity and reliability evidence of a general chemistry assessment

Taylor Humphreys, Casandra Koevoets-Beach, and Morgan Balabanoff (University of Louisville)

Assessing general chemistry knowledge is difficult due to the variety of concepts, systems, and contexts covered across a two-semester sequence. The Water Instrument assessment tool was created to account for these challenges by using the singular context of water for the assessment of general chemistry knowledge. The Water Instrument is a 38-item instrument targeting general chemistry students' learning of eight of the ten General Chemistry Anchoring Concepts defined by the American Chemical Society. The assessment is structured in a two-tier format where each multiple-choice content question is paired with a confidence tier which asks the students to rate how well they were able to answer the question.

This assessment was administered at the University of Nebraska-Lincoln in the spring of 2021 to 463 students (Balabanoff, 2022). The assessment was administered again at the University of Louisville in the spring of 2022 with a population of 212 second-semester general chemistry students. Assessing a new population of students with the same instrument leads to a better understanding of the instrument's functionality. The second administration of the instrument was carried out to investigate if the Water Instrument assessment can produce valid and reliable data with a new student population.

Item Response Theory (IRT) was used to analyze the data from the assessment administration. IRT models the relationship between student ability (in this case students' general chemistry knowledge), assessment item difficulty, and probability of correct response (Albano, 2020). With open-source coding software, R, IRT was used to evaluate the assessment through parameters including difficulty values, fit statistics, and RMSEA values. In addition to these parameters, a Wright map and frequency distribution chart were generated to determine how the assessment measured a range of student abilities.

The analysis of the data collected at the University of Louisville was found to independently support validity of the instrument and its individual items. When compared to the analysis of the University of Nebraska-Lincoln, the data showed consistent results that support the use of this assessment with a new population. These pieces of evidence support the use of the Water Instrument as a measure of general chemistry content knowledge.

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Exploring retrieval difficulties and self-confidence in the assessment of general chemistry students

Karen Julian, Casandra Koevoets-Beach, and Morgan Balabanoff (University of Louisville)

To comprehend how limited knowledge, shortcomings, and feelings of uncertainty affect performance and pursuit of STEM success, undergraduate students must be able to accurately assess their own confidence (Thompson, Prowse Turner & Pennycook, 2011). Previous studies have shown that some students are able to accurately evaluate their knowledge, but many students are not (Connor, Glass & Shultz, 2021).

One of the first science courses that STEM undergraduates take is General Chemistry which provides an excellent opportunity to learn about the viewpoints and level of confidence that students have with their science knowledge. The focus of this study was investigating how students evaluate their own confidence while answering multiple-choice assessment items targeting general chemistry.

Using an assessment developed for the year-long sequence of general chemistry, students were asked to rate how well they were able to answer conceptual questions. After students completed the assessment, cognitive interviews were conducted to investigate the variety of ways students evaluated their confidence. Transcripts from four students' interviews were analyzed to characterize this thought process. Detailed information was elicited from these interviews regarding the ideas, opinions, and attitudes that influence student behavior. The analysis of these interviews included identifying the ways in which students determined their confidence and identifying overall themes (Miles, 2015). Further investigation was done focusing on the correlations between student performance, mental process, and confidence.

Through this analysis, it was found that they rely on a variety of factors to evaluate their confidence outside of their content knowledge including doubt, retrieval difficulty, and test-taking strategies. These findings suggest that more explicit instruction may be needed to promote accurate self-assessment. Students can also develop their metacognitive skills and calibrate their perceived ability through continued practice with assessments that are designed to convey an awareness of content knowledge gaps.

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Exploring students' epistemological understanding of atomic structure models

Claire Ward and Morgan Balabanoff (University of Louisville)

Developing a robust understanding of atomic structure and the nature of matter is foundational across chemistry and STEM courses. The development of this concept is challenging because it relies on models to illustrate something not directly observable. Scientific models are important tools used to explain phenomena, particularly phenomena that are not directly observable. In general chemistry, students are typically asked to consider four different models: (1) the particle model, (2) the nuclear model, (3) the Bohr model, and (4) the Quantum model. Each depiction has its own advantages and limitations, where instructors introduce each model to explain specific parts of an atom. However, little evaluation is done by instructors on students' epistemological understanding of the nature of models which could impact how they interact directly with atomic models.

Previous research indicates that 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). Students are most comfortable with the Bohr model as it shows electrons orbiting the nucleus (Roche Allred & Bretz, 2019). Students have found it difficult to connect probability to the depiction of an electron cloud and tend to rely on classical ideas (Papageorgiou et al., 2016; Roche Allred & Bretz, 2019; Zarkadis et al., 2017). By relying on the classical and simplistic Bohr model, students may struggle to explain more complex concepts in future courses, such as resonance.

In this study, students' understanding of the nature of models and how they applied that understanding in the context of atomic models was investigated. Semi-structured interviews were used to elicit students' epistemological understanding of models and their general understanding of atomic structure. For instance, students were asked to explain how scientists generate models and identify the characteristics of a good scientific model. Subsequently, students were asked to explain ideas such as nuclear attraction and probability using the four different models described above (1 - 4) to investigate which features students attend to for specific concepts.

Results from this qualitative study include the variety of ways students understand and conceptualize models of an atom as well as how their general notions of the nature of models play a role in their conceptualization. The implications for introducing atomic structure models and promoting an epistemological understanding of models in general chemistry will be discussed.

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Measuring response confidence: Exploring an affective construct within a general chemistry assessment

Casandra Koevoets-Beach, Morgan Balabanoff, Karen Julian, and Taylor Humphreys
(University of Louisville)

Pairing content measures with a confidence tier is a common practice in assessment design to evaluate students' confidence-accuracy calibration. Dunning and Kruger established that miscalibration of confidence and ability is often observed in individuals who lack metacognitive skills (Dunning & Kruger, 2000). It has also been argued that confidence is the product of metacognitive monitoring and that a confidence estimate may aid in the recall of a concept in recent, working memory (Stock, 1994).

Analysis of the relationship between students' reported confidence with their measured ability or content knowledge has been notably utilized in the development of chemistry concept inventories (Abell, 2019; Atkinson, 2020; Brandriet, 2014; McClary, 2012; Roche Allred, 2019), representational chemistry assessment tools (Connor, 2021), and physics and biology education assessments (Eryilmaz, 2010; Saat, 2016).

The comparison of students' confidence rating and ability is often used to identify misconceptions or "false positives" of content knowledge in two- or three-tier assessments (Treagust, 1995; Hasan, 1999). Confidence ratings have also been used to identify students with miscalibrated confidence consistent with the Dunning-Kruger effect (Brandriet, 2014). Despite the widespread use of these techniques, it is unclear what is being measured when students report their confidence in a paired question assessment. The efficacy of measuring confidence as a construct of interest is so far under-explored in the context of science assessments.

This mixed-methods study uses a previously published two-tier assessment tool designed to elicit students' deep conceptual knowledge in a year-long General Chemistry sequence (Balabanoff, 2022) to investigate student confidence. The assessment data collected in this study was psychometrically analyzed using Item Response Theory, and cognitive interviews were subsequently performed to explore students' response processes for both the content and confidence tiers of the instrument.

Results will be presented by 1) evaluating validity and reliability of the content tier, 2) exploring the factors students used to rank their confidence, and 3) discussing themes observed in the relationship between students' confidence rating and content knowledge.

The measurement of students' response confidence is a well-established tool to assist in the understanding of content misconceptions; however this study seeks to further explore how students evaluate their confidence and how that relates to the content knowledge that educators are interested in assessing. A more thorough understanding of what is being measured when students are reporting their confidence would provide both those who design assessments and those who utilize them in the classroom with a more accurate measurement of the confidence construct to better assist in scaffolding students' metacognitive processes.

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Student discourse networks and group composition in a POGIL-based general chemistry class

Karolin Abouelyamin, Sylvia Zakher (Middle Tennessee State University), Joshua Reid (Texas Tech University), and Gregory T. Rushton (Middle Tennessee State University)

Active learning improves student performance in science, technology, engineering, and mathematics (STEM) courses and narrows achievement gaps between underrepresented minority groups and non-underrepresented groups. Nevertheless, recent research sufficiently demonstrates that the effectiveness of active learning strategies is influenced by several factors, including class size, instructor facilitation, and student diversity. Because student diversity plays an essential role in an active learning classroom, we dedicated part of our research to study an underrepresented group of students in the research field: English Learners (ELs). As the diversity of students in STEM courses continues to rise, it is important to ensure that the pedagogical activities support all students.

This study aimed to characterize discursive networks among students working in a small group setting and how patterns in student discourse could differ based on group composition (based on EL status). It is important to analyze how group composition affects student engagement in small group settings to learn how to design a learning environment that promotes knowledge construction. Our data consisted of audio recordings from group conversations of students enrolled in a general chemistry course at a large Southeastern university in the United States. The instructor of this course was a trained Process Oriented Guided Inquiry Learning (POGIL) instructor and incorporated POGIL in the course. The following research question guided our study: What is the relationship between group composition (i.e., EL status) and student discourse network in a collaborative, POGIL-based, introductory General Chemistry course?

Three small groups were chosen (viz. Alpha – 4 non-ELs, Delta – 2 ELs & 2 non-ELs, and Foxtrot – 4 ELs) based on the number of individuals who identified as an EL. We examined the selected groups across three class meetings. Class meeting dates were selected based on which had the most talk turns. The selected class recordings from three groups were analyzed and interpreted using established qualitative frameworks to make sense of student-student interactions. After coding the nature of each student utterance according to the Student Interaction Discursive Moves (SIDM) framework, the Social Newtwork Analysis (SNA) framework was used to generate network sociograms for each of the chosen cases. The sociograms were utilized to visualize the effects of students' EL status on their group engagement and discourse.

Findings from our previous research showed that ELs engaged less in constructive discursive moves that can lead to knowledge construction than non-ELs. Preliminary sociograms showed that as the number of ELs students increases in a group, the instructor becomes more central in the conversation. For example, the instructor was less involved in the discourse of alpha group than delta group. In addition, we expect to find that the group composition (i.e., EL status of the group members) will affect EL students' number of talk-turns. In other words, we expect EL students to engage less if they were put in a group of solely ELs students rather than a group with both ELs and non-ELs students.

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Exploring how empathy education changes students' perceptions of an "engineer"

Libby Flanagan and Karen High (Clemson University)

There are so many skills that the 21st century engineer needs to have: communication, working on international and interdisciplinary teams, working in developing economies, and personal skills such as empathy (Hess et al., 2016; Walther et al., 2012; Weichert et al., 2001). Success in the workplace not only relies on technical knowledge but these skills that allow for a well-rounded engineer. Additionally the infusion of these skills, such as empathy, have been shown to humanize engineering problems and therefore increase interest and sense of belongingness in STEM from under-represented groups (Burns & Lesseig, 2017). Engineers with more empathy can make better designs for a diverse population, such as considering the needs of someone who uses a wheelchair (Algra & Johnston, 2015). Infusing these topics into engineering education helps to frame engineering as a caring profession (Capobianco & Yu, 2014) which may attract girls' socially influenced empathic preferences (Fine, 2012).

Empathy can be emotional, descriptive, or applied to design (Algra & Johnston, 2015; Burns & Lesseig, 2017). The emotional and descriptive side can be seen in the characterization by Walther et al. (2017) as a way of being, an orientation, and a learnable skill for engineers. This model informs the material that was created to be included in engineering curriculum (Sochacka et al., 2021) that was adapted to this study's context following the propagation paradigm (Froyd et al., 2017). Engineering identity framework is used as it is an indicator for persistence through school and professional success (Godwin & Potvin, 2015; Marra et al., 2009; Meyers et al., 2012). The framework used by Godwin (2016) adapted from Hazari et al. (2010) focuses on three main concepts: interest, performance or competence, and recognition. Interest is defined as "the desire/curiosity to think about and do well in engineering" (Godwin, 2016). Interest includes their enjoyment and fulfillment doing engineering work. Performance or competence is the belief in ability to perform required tasks and understand content. This includes their confidence in and outside of class and ability to do well on exams. And lastly, recognition as the feeling that others, such as parents, instructors, and peers, see them as a good student. This framework will be used to indicate the successfulness of humanizing engineering work through empathy by increasing engineering identity and interest in female and non-binary individuals.

The following questions will be explored to better understand how this curriculum can be incorporated into a first-year classroom and explore the role of empathy in engineering identity:

RQ1: How do first year students' perception of the role of an engineer change based on the incorporation of empathy lessons into the classroom?

RQ2: What are the salient features of empathy instruction that first year engineering students retain?

RQ3: How does engineering identity and persistence change with exposure to empathy education amongst female and non-binary students?

This study is a multimethod study (Anguera et al., 2018; Johnson et al., 2007) that will use qualitative methods to answer RQ1 and RQ2 and longitudinal quantitative methods to answer RQ3. In the pilot study in the Fall of 2022, first year students in the honors sections of "Introduction to Engineering" (ENGR 1020) at a large R1 university will receive four 50-minute empathy modules. Example lessons include role play scenarios of the Flint water crisis where they engage as the engineer with community members with varying concerns. At the end of each module there will be a short-written reflection and a reflection at the end of the semester. The changes in reflections over the four modules will be analyzed for RQ1 and the salient features at the end of the semester for RQ2. Students will also take a pre and post-survey on empathy developed by Hess et al. (2018). Questions from the Motivations and Attitudes in Engineering (MAE) survey will also be included in the pre-survey and then pulled from the full MAE survey for the post-survey. Longitudinal comparisons will be made over the course of the MAE survey offering (since 2021) with an analysis on female and non-binary changes in engineering identity to answer RQ3. A confirmatory factor analysis will be performed on the pilot data from the Fall of 2022 to confirm the survey's use on first year students. This poster will contain the preliminary data and analysis that is to be collected from the Fall 2022 semester.

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Order matters for creating 3D representations

Jill Cochran, Cody Gordon, Sabrina Bagley, Zane Cochran, and Hannah Zemke (Berry College)

Several years ago, one middle and two elementary schools approached HackBerry Lab, an educational maker space, with a request for curriculum utilizing 3D printers to teach traditional mathematics topics in an innovative way. We have since published a website of supplemental curriculum and training resources freely available to teachers to use. As we began working with classroom teachers and their students on 3D design and printing projects, we found that some students seemed to understand and work well within the virtual 3D space, but many others struggled. In an attempt to help students prepare for design tasks, we utilized a common teaching practice within design-based teaching environments and required students to sketch or draw a plan before designing it on the computer (Jurgenson & Delaney, 2020; MacDonald & Gustafson, 2004; Thom & McGarvey, 2015; Welch et al., 2000). This was met with mixed results, which led to questions about how students develop 3D representation skills and how teachers can design tasks to shape understanding of 3D structures.

While understanding of the importance of 3D representations is relatively well documented, how students develop these skills is not. The majority of research about the development of representations of 3D objects focuses on 2D representations such as projective drawings of simple 3D objects (Mitchelmore, 1980) and perspective (front/side/top) views (Sack & Vazquez, 2016). The use of sketches or drawings is prevalent in design education research with two main purposes: to represent understanding of 3D structural elements and the creation of new ideas. Several researchers (Hope, 2000; Jurgenson & Delaney, 2020; Thom & McGarvey, 2015; Smith, 2001) have argued that most design tasks for students overemphasize the former and underemphasize the latter. Their rationale seems to focus on the principle that student (and professional) sketches are simpler and more abstract allowing for some ambiguity that leads to the creation of new ideas (MacDonald & Gustafson, 2004; Smith, 2001). Jurgenson and Delaney in researching a classroom design activity with 5-year-olds had students use drawing both before building physical models as part of the ideation process as well as afterward as a representative documentation of the physical models. This sequence of activities successfully helped tie together mathematics, science and engineering principles. However, the transfer between processes that involve different modes of representation needs to be further researched. Welch, et al. (2000) calculated that the Grade 7 students that they were working with spent only about 8.5% of their total design time sketching and drawing, choosing to jump fairly quickly into other modes of representing their design ideas. Students' reluctance to use drawing or sketches might be because of differences that Tseng (2018) noted between novice and designers' sketches related to their ability to visualize the sub-shapes of an object and generate a helpful illustration.

Whatever the reasons, it seems apparent that students do not equally value or utilize different representations of 3D objects. Taking it one step further, Rogers (1998) found only a "weak link existing between the children's designing stage and their making and appraising stages" (abstract) and cited complicated reasons for this weak link. Our research informs the processes of designing 3D objects in multiple representations, specifically examining how one stage in the process can influence the following stage(s). In addition to 2D representations, we also include interactive representations on a computer and the creation of 3D objects.

Methods

In a study designed in collaboration with undergraduate pre-service teachers, we examined the research question: What order of 3D modeling activities is most effective for students' development of the ability to create models of 3D objects? We asked students in 29 classes, first through ninth grades (odd grades only), in six public and private schools to do the following tasks. They were asked to represent three objects ranging from simple to complex: a cube, an observed cube with a corner missing, and an imagined bench each using three different representations in a random order: building with cubes, drawing on paper, and designing using simple 3D computer software. Rubrics were created for all tasks from pilot data across two 3-point scales: accuracy in representation of the assigned object and three-dimensionality. Each of the 512 students' drawings, computer designs, and buildings were evaluated by at least two trained reviewers. Discrepancies in scores were discussed and then evaluated by a third reviewer and these scores were averaged. Based on statistical analysis, we decided to further explore students' computer designs and drawings that scored above average on one and below average on the other, coding them for common issues and similarities.

Results

We found that students develop the skills required to accurately draw 3D objects slower than either building or designing them on a computer. The ability to draw objects that both look 3D and representative of the given object or task improved significantly with each grade level from first through seventh grades. On the other hand, even as early as first grade, students are fairly proficient at building 3D objects from blocks. This ability is consistently the highest for each grade level. The ability to design representations on a computer averaged between the drawing and building abilities at all grade levels. The designing averages saw the most discrepancies between different schools, possibly due to access to and familiarity with technology. Therefore, we intentionally collected data from a variety of schools at each grade level except ninth grade where data from only one public school was available.

With such a significant difference in demonstrated ability to produce these different types of representations, especially at a young age, we next looked at the scores for each task based on the order in which students were assigned to complete the different types of representations. Our research question was stated with the intention of determining, for example, if students would perform better on drawing an object after having built that object. We hypothesized that students who completed a task that they were more proficient in might then be able to transfer that experience to a more unfamiliar representation of that same object. With three representations, there were a total of six different orders that students were randomly assigned, keeping the same order for both the cube with a corner missing and the bench tasks. For each type of representation (draw, build, and design), we then compared average scores for each order. When this did not show any significant differences, we grouped the data to examine, for example, drawing scores for students whose order had them draw first compared with students who designed just before drawing or built just before drawing. These averages and statistical tests suggest that students create better designs on the computer if they have not drawn or built it first.

Beyond examining the order of representations, we used additional information collected from each student to explore other significant results. Unsurprisingly, students with 3D design experience performed better with the computer design tasks when compared with the 97 students who had no computer design experience. What was more surprising was that these students with computer design experience also showed more proficiency with the drawing and building representations as well. This suggests an overall better understanding of 3D objects than students of a similar age with no computer design experience.

Teachers and those wishing to develop 3D representation skills can conclude from the results of this study that being able to effectively represent 3D objects in one way does not translate into ability with other representations. Finally, the development of 3D representations as ways of visualizing the structure of objects and the world around us, has interdisciplinary implications in math, art and technology education.

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Learning astronomy with the use of wearable augmented reality

Michael Hein, John Wallin, Andrienne Friedli, Brenna Armfield, Ayat Tamimi, and Isaac Shirk
(Middle Tennessee State University)

Introduction

Active learning has been clearly demonstrated to impact student performance in STEM fields. (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt Wenderoth, 2014). Augmented reality has the potential to boost student's motivation and attainment (Cen, Ruta, Quassem and NG, 2020). This study explores the effects of experiencing a traditional astronomy lab in augmented reality on student motivation and learning.

Methods

Experimental condition participants were randomly selected from Astronomy lab sections at the beginning of the laboratory course. The selected exercise explores the origin of moon phases in the Sun, Earth, Moon (SEM) system from the perspective of an observer. Students who remained in the normal instructor led lab session served as the control condition. Participants either completed the lab using an augmented reality environment or stayed in the classroom and learned the material through traditional methods (instruction by lecture). The Magic Leap wearable AR system allowed participants to interact with three-dimensional projections of the SEM system within the real world. The AR device also collected data about the user interaction with the technology during the intervention. The software, including the SEM application, was written by the research team for the project. All participants completed a series of individual difference measures in spatial ability and working memory capacity before completing the lab. After the lab was completed, students were asked to fill out the Intrinsic motivation scale and take the Moon Lab quiz traditionally used for this astronomy lab. The Intrinsic motivation scale is 5 questions assessing the engagement of the subjects in the task, the items are rated on a 7-item scale for a range of possible scores from 7 to 35. The Moon Lab quiz is eight multiple choice items scored right or wrong. This is a difficult lab and students traditionally struggle with these concepts and misconceptions about the SEM system.

Results

The participants in the augmented reality (AR) condition had a mean intrinsic motivation score of 31.15. The participants in the traditional lab had a mean intrinsic motivation scale of 16.19. The results were significantly different $T(112)=23.71$, $p<.001$. Participants in the AR condition had a mean quiz score of 5.10 and participants in the traditional lab had a mean quiz score of 4.16. The results were significantly different $T(112)=2.36$, $p=.020$.

Discussion

Motivation affects the direction, intensity and persistence of behavior (Kanfer, Freese & Johnson, 2017). The difference in intrinsic motivation between these two learning experiences could drive changes in behavior that greatly improve learning over time. While the effects on quiz performance are smaller they are still significant. The quiz is also the traditional quiz used with this lab and was not designed to focus specifically on concepts that may be better learned through the use of augmented reality.

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CyberLearnAR: The development of a wearable augmented reality system for teaching STEM

John Wallin, Isaac Shirk, Rafet Al-Tobasei, Andrienne Friedli, Michael Sharp, Nico Kaszynski, Austin Fine, and Michael Hein (Middle Tennessee State University)

Augmented Reality (AR) technologies are associated with adding images to the user's real-world environment. The goal of the CyberLearnAR project is to explore the potential impact of emerging augmented reality technology on STEM classrooms and learning. Most previous efforts have focused on mobile phones or similar devices to explore their effectiveness in STEM teaching. (1,2,3) Our system uses the newest generation of AR/Spatial Computing (SC) headsets, so that students can view and manipulate 3D holographic objects in collaborative learning environments.

Because this is an emerging technology, the software framework was developed, and the lab implementation was created at MTSU. The software system was developed within the Unity Game development environment. This system provides a buffer that allows the educational content to work across new AR platforms as they evolve. Within the framework, content developers can design laboratories suitable for STEM classrooms. Laboratories are built from content modules, and each module contains audio cues, interactions, activities, or changes within the current scene to support learning and guide the student through the paper lab.

The first version of our software framework was completed last year. In mid-2022, we merged the system with the web system to distribute labs to headsets efficiently and record user interactions during testing on human subjects.

The first lesson implemented within the system was designed to teach Introductory Astronomy students about moon phases. The laboratory was based on the current classroom laboratory on this topic used in the ASTR 1031 course. The AR laboratory was designed to address three common misconceptions about the Earth-Moon system seen across astronomy:

- Sizes and Scales – students often underestimate the distance between Earth and Moon and overestimate the relative size of the moon. (4,5)
- Synchronous rotation of the moon – students often think the moon does not rotate. (6)
- The cause and sequence of moon phases – students often think moon phases are caused by the shadow of the Earth, not by a spherical body being illuminated by the Sun. (7,8)

The software and the laboratory were first tested in the Fall of 2021, and additional testing is underway during the Fall of 2022. Preliminary results from this work are being presented in another poster at this conference, "Learning Astronomy with the Use of Wearable Augmented Reality." The current generation of testing involves tracking student behavior by the positioning and orientation of their headsets. This work is being presented in another poster as well "Measuring Learner Behavior using Wearable AR."

The preliminary results of this study are promising. The software creates a flexible environment for implementing STEM content that can help students visualize complex phenomena. Early results suggest that the technology effectively supports learning and provides an engaging environment.

Implementing multiuser interactions within the AR environment will be completed in late 2022 or early 2023. Wearable AR is expected to be effective in small group learning settings since users can see each other and the augmented world. We hope to test this technology in the Spring of 2023 to assess changes in the student interaction with the technology and learning gains associated with this system.

This material is based upon work supported by the National Science Foundation under Grant No. 2017011.

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Describing how teacher questioning elicits student thinking in an interdisciplinary STEM lesson

Lori Klukowski, Seth Jones, Fonya Scott, and Sara Salisbury (Middle Tennessee State University)

Introduction

Teachers' questions during class discussions play a key role in eliciting student thinking (Chin, 2007; Kayima & Jacobsen, 2020; Van Zee & Minstrell, 1997). By posing the right question, teachers help students explain an idea, make a prediction, or make connections about disparate ideas (Chin, 2007; Yip, 2004). Teacher questions can aid students to elaborate on their own or other students' statements or to challenge an alternative conception (Chin, 2007; Yip, 2004). Effective questioning strategies uncover student thinking, and thus provide valuable information about student learning (Araceli Ruiz-Primo & Furtak, 2006; Van Zee & Minstrell, 1997).

Developing and enacting effective questioning strategies in classroom discussions takes considerable knowledge and skill. These strategies require both deep knowledge about the content taught and knowledge of the students (Heritage & Heritage, 2013). This type of knowledge and skills unique to teachers is known as pedagogical content knowledge (PCK) (Shulman, 1987). We conceptualized PCK has having three dynamic and interacting domains: the sum of knowledge held by a community of professionals (collective PCK), the professional knowledge and skills held by an individual teacher (personal PCK), and the knowledge and skills used to plan and teach a particular topic or concept to particular students (enacted PCK) (Carlson et al., 2019). The strategies teachers use to reveal student thinking in the act of teaching are situated in the domain of enacted PCK (Wilson et al., 2019). Because knowledge flows among these three domains (Carlson et al., 2019), questioning strategies enacted in the classroom draw upon the individual's professional knowledge and the professional communities' knowledge. By observing the use of teachers' questioning in the classroom, we can begin to understand the personal and community PCK required to support student learning.

Developing effective teacher questioning strategies can be difficult for all teachers, but interdisciplinary learning environments create additional challenges because they require teachers to have deep content knowledge in several disciplines and the ability to help students make connections across disciplinary boundaries. Therefore, teachers may not be prepared to ask questions that uncover students' thinking about knowledge and practices outside of the teachers' experience or help students make cross-disciplinary connections. This explains why one current goal for interdisciplinary STEM (iSTEM) research is to better understand the PCK required in iSTEM contexts to effectively support student learning (Honey et al., 2014).

With this goal in mind, we sought to better understand teacher questioning strategies in an iSTEM lesson. To better understand questioning strategies, we explored teacher questions that elicited student thinking in a purposefully sampled iSTEM lesson focused on data modeling within the context of plant growth measurements. Our study was motivated by the question: in what ways do teachers use questions to elicit student thinking in iSTEM whole class discussions?

Methods

This pilot 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. We analyzed the video recording of a whole class discussion of one sixth grade mathematics teacher discussing data on plant heights collected in science. We chose this recording because it was an example of cross-disciplinary teaching, i.e., the mathematics teacher was discussing both mathematics and science concepts and practices, and because it had a high density of questions (78 questions in 17 minutes). In addition, this teacher has many years of experience teaching mathematics and has served as an instructional leader for both mathematics and science. Because we conceptualized questioning as enacted PCK, which is always situated within a specific learning context, we took a sociolinguistic stance during analysis. We sought to understand the context of the question, the content of the questions, and the chains of the teacher's and students' responses before and after questions to characterize this teacher's practice (Carlsen, 1991; Chin, 2007; Kayima & Jacobsen, 2020). Therefore, the unit of analysis was the question and the discourse surrounding it. We analyzed the video recording directly to capture nonverbal responses to teachers' questions. Because we were interested in describing the types of questions asked in an iSTEM lesson, we included in our analysis the discourse of the principal investigator of the larger study and a graduate student who were also present during the lesson and were participant observers in the classroom.

In our analysis, we first coded the video recording to indicate which utterances by the teachers were questions. An utterance was coded as a question if it had the grammatical form of a question, e.g. "Why?", if there was an incomplete sentence ending with rising intonation and a pause, e.g. "We measured the height because . . .", or if it were a rhetorical statement ending with rising intonation, e.g. "You remember when you measured, right?". Once we established segments of the recording as questions, we did a second round of open coding to describe the context and content of the question, and the response of the students (Carlsen, 1991). We watched the segments immediately prior to and after the coded question several times and wrote descriptive memos regarding the context and content of the question, and the response of the students. We included both verbal and nonverbal responses of the students, i.e., head nodding, in the description. Finally, we considered those question segments which resulted in rich verbal responses from students to be target questions that elicited student thinking. We categorized these questions according to their function in the surrounding discourse.

Findings

Preliminary results indicated that teachers used three types of questions to elicit student thinking in an iSTEM lesson. Teachers asked questions for explanation, e.g. "Why?", and questions for causation, e.g. "What caused all this variation?". The most common type of question to elicit students' thinking, however, were questions that responded to a student statement, and then elicited further elaboration or clarification, e.g., "Okay, how they were planted [student answer], what are some differences in how they were planted?". In this poster presentation we will describe the types of questions used to uncover student thinking, how they relate to interdisciplinary content, and some implications for developing teachers' PCK in iSTEM education.

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Digital agriculture summer camp: an examination of non-formal learning to promote knowledge and postsecondary STEM interests

Carly Altman and Chaney Mosley (Middle Tennessee State University)

Introduction and Literature Review

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, and Scouting (Sefton-Green, 2012). 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). Short-term educational camps can have a positive impact on students, including their learning achievements (Foster & Shiel-Rolle, 2011); though, no studies have investigated agriculture-based camps. Therefore, the purpose of this pilot study, funded by USDA-NIFA award # 2021-67037-35972, was to describe the impact of a digital agriculture summer camp on camper knowledge and postsecondary interests.

Research Questions

Digital agriculture involves the interdisciplinary development of technology on the basis of precision agriculture to collect, integrate, and transmit data into decision-making tools. The three focus areas of camp 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 campers recommend improving the digital agriculture camp experience?

Methodology

This study 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). On the last day of camp, participants were asked to complete a five-point Likert-type researcher-designed survey. The survey had a section about knowledge, asking how much campers knew about subjects covered in camp (1 = very little; 5 = very much); and a section asking campers to indicate their level of agreement with interest statements (1 = strongly disagree; 5 = strongly agree). An open-ended question about the camp experience.

Data Analysis and Results

Completed surveys (N = 11) were analyzed and descriptive statistics were used to describe the sample and measures. For all three areas of focus (agriculture, aerospace, and data science), there was an increase in knowledge (80%, 128%, and 96%, respectively) and interest in related postsecondary education and careers (13%, 29%, 33%). 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).

When asked how to improve camp, a consensus was less talk, more action. In a non-formal, camp setting, students want to receive information in chunks. At first, they want just enough knowledge to play with new tools and develop ideas; later they want more explanation.

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Digital storytelling reimagined: a framework for data literacy and interdisciplinary learning in K-12 classrooms

Tisha Brown-Gaines, Mary Ellen Pethel, Heather Finch, and Emmanuel Saka (Belmont University)

A September 2020 survey by the National Education Association reported that 75% of children living in households in the United States have a device other than a smartphone [1]. The demographics of the study included children aged 5 -17. This represents a snapshot of the digital access of students in K-12 classrooms around the country. It is an understatement that students live in a digital world with access to devices and endless amounts of data. The daily interactions with these devices affect every aspect of how they learn, socialize and live [2]. George Westermann of MIT said, “When digital transformation is done right in business, it’s like a caterpillar turning into a butterfly, but when done wrong, all you have is a really fast caterpillar.” We envision a classroom setting where all students strive to become butterflies by implementing a similar narrative in education [3]. To achieve our objective, we implemented a framework to integrate digital storytelling over a broad range of topics including literature, mathematics, history and technology. Using the Digital Storytelling approach, we designed a course to provide students the ability to gain new skills and experiences to better understand how to navigate this new era of digital access, information overload and technology utilization.

What is the Data Storytelling ?

Simply stated, digital storytelling is the ability to work through a problem from a data perspective and then explore, analyze, and tell a story to compel action and decision making. In the course, we identified a process for students to understand principles for data literacy and empathy based problem-solving skills via creative and critical thinking [4].

How can we measure its effectiveness ?

During the summer of 2022, a program was developed to provide students with an opportunity to experience learning via the Digital Storytelling framework. The framework included a three-part process which included: discovery, insights and action. The first cohort of students consisted of twelve rising seniors from Metro Nashville Public Schools all nominated by their school administrators. The three-week program was an on-campus opportunity to take a college-level course. The course provided students with an understanding and reviewed methodologies for data literacy, digital storytelling, creativity and innovation. The topics explored increased their knowledge on how to think creatively using data literacy and understanding ethics. By integrating the framework students logically applied data through an interdisciplinary lens. Research involving data methods, ethics, sources, computer science, history, design and public policy formed a basis of skill and knowledge. These skills and knowledge were used to identify a problem and utilize data to solve it in uniquely identified areas.

What problems were identified by students?

Rising seniors who participated in this program worked with an interdisciplinary group of faculty members (political science, experiential design, history, English, business, and computer science) and also partnered with the Belmont Data Collaborative. This collaboration resulted in students generating questions about affordable housing in Nashville, analyzing data sets related to affordable housing using Tableau, producing an Infographic using Canva, and presenting their findings in a poster session attended by more than 100 community members. Some of the problem statements are listed below.

- Based on different demographic categories, where is it possible to find affordable housing in Nashville?
- How can data be used to tell the story of Nashville's past and present affordable housing crisis?
- What historical factors played, and continue to play, a role in the trajectory of affordable housing?
- In what ways can visual data be used to communicate residential and economic trends in Nashville?

What was achieved?

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

- Create a data story to be used for decision-making and impact actionable change?
- Can K-12 students apply principles for data literacy and storytelling into real world cases?

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Identifying USAFA majors susceptible to STEM attrition through major flow analysis

Wilson Gonzalez-Espada (Morehead State University), Daniel S. O'Keefe and David Meier (United States Air Force Academy)

Background. In increasingly technological civilian and military worlds, professionals in science, technology, engineering, and mathematics (STEM) are essential. To what extent postsecondary institutions are providing quality support to STEM-interested students is subject to debate, but the consensus is that STEM attrition at the college level is problematic and is a topic of intense study (Brewer et al., 2021; Chen, 2015; Dwyer et al, 2020; Sithole et al., 2017; O'Keefe et al., 2022; Seymour & Hunter, 2019).

Significance. Reducing STEM attrition is important for the military. Given the rapid pace of technological advancement, education, particularly in STEM, is key to maintaining military superiority (Air Force Research Laboratory, 2022). The U.S. Department of Defense have identified a vigorous STEM workforce as essential for a strong military and an evolving and increasingly complex national and international security environment (National Academies of Sciences, Engineering, and Medicine, 2015; National Research Council, 2014, 2012a, 2012b, 2010).

Research Questions. (a) To what extent are cadets who change their original STEM major remaining within STEM as Persisters or becoming STEM Departers? (b) Which STEM majors experience the most and least attrition, by sheer numbers and as percentages of total initial enrollment? (c) Which factors contribute to STEM attrition?

Data Analysis. This study relied on data from the Office of Student Academic Affairs and Academy Registrar collected monthly during AY 2019-2020, 2020-2021, and 2021-2022. Because of the data's categorical nature, analyses consisted of descriptive statistics and Chi-Square tests when appropriate.

Findings. Of 738 cadets who changed majors, 38.1% were STEM Persisters, 28.3% were STEM Departers, 27.5% were nonSTEM Persisters, and 6.1% were STEM Arrivers. The ratio of STEM Departers to Arrivers is almost 5 to 1. In terms of the raw number of cadets, the top three STEM majors where cadets switched to nonSTEM the most were Biology, Computer Science, and Aeronautical Engineering. The top three STEM majors where cadets switched to nonSTEM the most per capita were Cyber Sciences, Data Science, and Computer Science. The three STEM majors where cadets switched to nonSTEM the least were Meteorology, Data Science, and Civil Engineering. The three STEM majors where cadets switched to nonSTEM the least per capita were Mechanical Engineering, Meteorology, and Astronautical Engineering. Most cadets who declared a STEM major either persisted in that major or switched to a different STEM discipline. Mathematics course requirements appeared to account for a sizable proportion of major flow out of STEM majors, as cadets moved from majors with five and six required math classes to those requiring two or three, which happen to be nonSTEM majors. Further mixed- methods research, like focus groups or surveys, may be able to untangle these variables at USAFA and their association with maximizing GPA. The researchers proposed four recommendations to gain insight into undeclared cadets' preference for STEM or nonSTEM, strengthen math proficiency across the board, reduce the course load of STEM-interested first-year cadets through virtual instruction prior to matriculation, and interview cadets to obtain first-person accounts of factors that contributed to STEM attrition.

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Initial impacts of a STEM professional learning institute for preschool educators

Alissa Lange and Amie Craven (East Tennessee State University)

Background Literature

Early math (Watts et al., 2014), science, (Grissmer et al., 2010), and STEM learning (McClure et al., 2017) influence in young children's educational trajectories, but not all children receive equitable access to these experiences (Beilock, et al., 2018). Research has shown that early childhood teachers' knowledge, attitudes, beliefs, and confidence toward supporting STEM learning directly impact their teaching (Maier, et al., 2013). Many preschool educators report an interest in enhancing their STEM teaching but identify limitations in readiness to enact changes in their practice (Ginsburg, et al., 2008). Professional learning supports that are well-designed can positively influence these factors for preschool teachers, potentially increasing access to key early STEM experiences for all young children (Lange, et al., 2021).

Unfortunately, long-term, time-intensive supports, while effective (Sarama et al., 2004; Brenneman et al., 2019) are cost-prohibitive for many early childhood providers. One solution may be to build capacity with those who support teachers, including coaches, master teachers, and center directors, and to deliver professional learning experiences virtually. However, limited work has been done with these providers focused on preschool STEM.

The present study will examine the extent to which intensive, research-based content, repackaged into a virtual institute and focused on a turnkey model is effective in leading to changes in coaching practice and increasing reach. These research questions guide this study:

1) To what extent do PSI attendees report impacts of participation on their knowledge and confidence in supporting preschool teachers in STEM?
2) To what extent is the PSI approach able to expand the reach of our preschool STEM education professional learning supports?

Methodology

Design, Participants, & Instrument: This pilot study used survey design delivered to the 33 synchronous participants (1 male), who were from 16 states and 3 countries. Items in the online survey were developed by the research team and aligned to the content of the Institute. The survey was hosted in Qualtrics and included Likert-type response options. An example item was, "My confidence in supporting teachers has increased after participating in the Preschool STEM Institute in science." Participants reported the number of teachers served and shared additional information about the type of supports provided through their Action Plans and follow up emails.

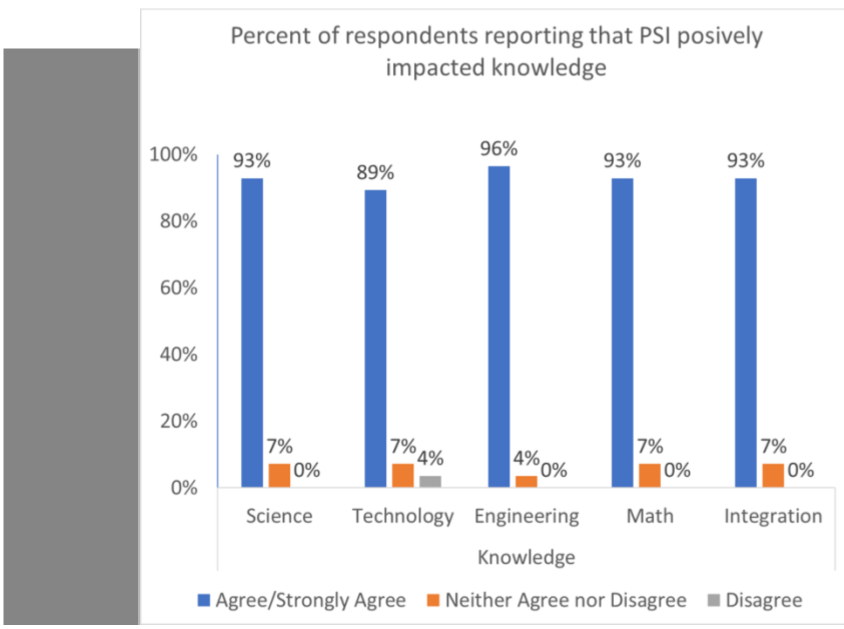
Program: The Preschool STEM Institute (PSI) is a virtual, interactive, hands-on, minds- on professional learning experience created for coaches, directors, master teachers, and anyone who supports preschool teachers. The purpose of the PSI is to increase knowledge and confidence in supporting STEM and integrated STEM teaching and learning. PSI was created to increase the reach and cost-effectiveness of our preschool STEM education supports, which were co-created with educators and researchers as part of two grants from the National Science Foundation. The participants are given a curated collection of resources to support their work that can be used following the PSI. Opportunities for follow-up training and professional learning communities are provided in the following year.

Procedure: After IRB approval was received, the PSI was delivered in summer 2021 and attendees completed consents and filled in surveys using a link provided immediately at the close of the Institute.

Results

Descriptive statistics are displayed below for N=28 respondents.

Figure 1. Percent of respondents agreeing or strongly agreeing that PSI attendance led to positive changes in knowledge in supporting each content area.



RQ 1) To what extent do PSI attendees report impacts of participation on their knowledge and confidence in supporting preschool teachers in STEM?

Table 1. Percent of respondents agreeing or strongly agreeing that PSI attendance led to positive changes in confidence in supporting each content area.

Science	Technology	Engineering	Math	Integrated STEM
97%	89%	93%	97%	93%

RQ 2) To what extent is the PSI approach able to expand the reach of our preschool STEM education professional learning supports?

The 33 participants reported plans to support 750 preschool teachers. This is well beyond the number of teachers who could be a part of our original NSF-funded project (N=50). The projects implemented by PSI attendees included a statewide book study in spring 2022 (Iowa), expanding a STEM Lab program in a public school (Texas), creating a community garden (Connecticut), and created an Early Numeracy training based on information learned at the Institute (Washington).

Discussion & Impact on the Field

Over 89% of participants agreed or strongly agreed with positive statements about the immediate impact of participation in PSI on their knowledge and confidence in supporting preschool teachers in S. T. E. M. and integrated STEM. Many of these were experienced professionals with many years of educational experience. The reach was expansive in terms of numbers of teachers served and the variety of ways in which participants were able to adapt the PSI content to their contexts.

Reducing cost while maintaining integrity of professional learning resources can increase access to high-quality early STEM educational experiences for a larger number of educators, and ultimately, of children. This poster will highlight the balance between maintaining the integrity of the original content and expanding reach, in a model such as this. In addition, we will discuss challenges of our approach that values differentiating the professional learning delivery (e.g., each attendee chooses a focus for their coaching based on individual contexts) and sustainability and assessment. We will discuss these issues across what is an incredibly diverse landscape of providers, with content, context, and even educational requirements of staff varying from center to center, town to town, and state to state. Future work includes analyzing data from the 2022 PSI and adding a teacher survey to include data from end users on the perceived impact of teachers who are supported by PSI coaches.

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Learn by teaching: learning biomedical informatics topics through intern-generated media

Robert Becker, Michelle Gomez, and Kim M. Unertl (Vanderbilt University)

Background Overview

A barrier to entry and success for any field is learning the core concepts and ideas used within an area of study. The field of biomedical informatics is broad and draws from a wide variety of backgrounds, including STEM fields. While primarily offered at the graduate level, institutions are beginning to offer clear pathways to biomedical informatics in undergraduate circles. This necessitates earlier exposure to biomedical informatics-related topics. During the last few cycles of our summer internship program, the Vanderbilt Biomedical Informatics Summer Program (VBISP), we've piloted a "design challenge" module. This module gives interns the opportunity to work collaboratively with their peers and develop tools and methods to define, plan, design, present, and receive feedback on their ideas. During the summer of 2022, the design challenge was to create a short video or self-published magazine (zine) to introduce a biomedical informatics-related concept to K-12 students. Interns also designed an experiment to test the effectiveness of their intervention. Upon completion of the internship, interns presented their chosen topic and intervention to a panel of experts and the rest of the department, outlining their rationale for choosing the topic and intervention, and the learning objectives of the intervention. Additionally, interns presented a proposed evaluation framework, sample evaluation questions, and their final product. The VBISP team surveyed the interns after the program to assess the module's impact on student learning and experience.

Significance of Research

The focus of this design challenge module was to create a zine or video designed to introduce a concept or topic used in biomedical informatics to children. Interns learned about the design process, how to evaluate the usefulness of an intervention, and how to practically communicate their ideas. The activity is meant to unlock each intern's creative nature and improve upon how they provide and respond to feedback. This project also gave interns the ability to develop their own research plan from start to finish.

Research Questions

Our focus for this project was with intern experience. We asked how interns felt doing the design challenge, what aspects were clear or unclear, what they enjoyed or felt challenged by, the time commitment associated with completing the project, experience surrounding peer-to-peer collaboration, and the skills they think they gained or wished they had gained from the project.

Data Analysis Procedures

The design challenge survey collected anonymous responses to questions surrounding their experiences.

Summary of Findings

Sixteen interns participated in this year's design challenge activity, forming four groups of three and one group of four. Two groups chose to create a zine while three groups created a video intervention. During one-on-one meetings with interns, general discourse about the design challenge activity was positive. We are currently processing the survey responses.

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