SSMA 2021

Virtual Conference • October 28 - 30

Proceedings - Volume 8

120th Annual Convention

October 28 - 30, 2021

Virtual Conference

Dr. Julie Herron

Editor

PROCEEDINGS OF THE 120TH ANNUAL CONVENTION OF THE SCHOOL SCIENCE AND MATHEMATICS ASSOCIATION

October 27-30, 2021
Virtual Conference
Editor: Julie Herron

Cite Proceedings Volume as:
Herron, J. (Ed.). (2021). *Proceedings of the 120th annual convention of the School Science and Mathematics Association* (Vol. 8). Virtual: SSMA.

Cite Proceedings Chapter as:
Author. (2021). Title of chapter. In J. Herron (Ed.). *Proceedings of the 120th annual convention of the School Science and Mathematics Association* (Vol. 8). Virtual: SSMA.

Website: www.ssma.org
The proceedings are also available via http://www.ssma.org/convention-proceedings

ISBN: 978-1-7343159-2-9

SSMA 2021 ANNUAL CONVENTION: VIRTUAL

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Special thanks to
The Publications Committee and SSMA members for reviewing and providing valuable feedback on the submitted manuscripts.

The School Science and Mathematics Association [SSMA] is an inclusive professional community of researchers and teachers who promote research, scholarship, and practice that improves school science and mathematics and advances the integration of science and mathematics. SSMA began in 1901 but has undergone several name changes over the years. The Association, which began in Chicago, was first named the Central Association of Physics Teachers with C. H. Smith named as President. In 1902, the Association became the Central Association of Science and Mathematics Teachers (CASMT) and C. H. Smith continued as President. July 18, 1928 marked the formal incorporation of CASMT in the State of Illinois. On December 8, 1970, the Association changed its name to School Science and Mathematics Association. Now the organizational name aligned with the title of the journal and embraced the national and international status the organization had managed for many years. SSMA focuses on promoting research-based innovations related to K-16 teacher preparation and continued professional enhancement in science and mathematics. Target audiences include higher education faculty members, K-16 school leaders and K-16 classroom teachers. Four goals define the activities and products of the School Science and Mathematics Association:

- Building and sustaining a community of teachers, researchers, scientists, and mathematicians
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For 120 years, SSMA has provided a venue for many of the most distinguished mathematics, science, and STEM educators to present research and publish manuscripts. The proceedings of the 120th Annual Virtual Convention serve as a testament to the Association's rich traditions and promising future.

Christa Jackson
SSMA President

PREFACE

These proceedings are a written record of some of the research and instructional innovations presented at the 120th Annual Meeting of the School Science and Mathematics Association held virtually October 27-30, 2021. The blinded, peer reviewed proceedings includes seven papers regarding instructional innovations and research. The acceptance rate for the proceedings was 100%. We are pleased to present these Proceedings as an important resource for the mathematics, science, and STEM education community.

Julie Herron
Editor

Herron, J. (Ed.). (2021). *Proceedings of the 120th annual convention of the School Science and Mathematics Association* (Vol. 8). Virtual: SSMA.

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ANALYZING K-5TH GRADE INTEGRATED STEM CURRICULUM IMPLEMENTED SINCE 2010

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Abstract

Science, Technology, Engineering, and Mathematics (STEM) education has received increased interest in the past decade. Integrated STEM education can provide students with relevant and meaningful experiences that develop STEM knowledge and 21st century competencies. One of the main concerns that have been raised for integrated STEM education is the need for further curriculum development where the STEM disciplines are integrated in a meaningful way. The purpose of this paper is to describe kindergarten to fifth grade integrated STEM education curriculum that has been implemented since 2010. Implications for further work with integrated STEM education curriculum are discussed.

Keywords: Curriculum; Elementary Education; Integrated STEM

Introduction

In a rapidly changing world, it is imperative that we educate well-rounded global citizens who are problem solvers with 21st century competencies who can conquer new challenges. Integrated Science, Technology, Engineering, and Mathematics (STEM) education is a vital way to help prepare students for their current and future lives. Integrated STEM education involves hands-on learning that is done through relevant open-ended problems that develop teamwork and communication skills (Stohlmann, 2019). It can motivate students learning in mathematics and science (Wendell & Rogers, 2013) and can lead students to be interested in STEM careers (Capobianco, Yu, & French, 2015). Integrating subjects also makes learning more connected and relevant (Stohlmann, Roehrig, & Moore, 2014).

Students need early exposure to integrated STEM education to build a strong foundation in STEM concepts and competencies. Because of this, there has been great interest in integrated STEM education at the elementary level (Stohlmann, Maiorca, & DeVaul, 2017). Elementary teachers new to integrated STEM education may be apprehensive at first and unsure how it can be implemented well (Tuttle, Stanley, & Bieniek, 2016). This highlights the importance of well-design curricular resources for integrated STEM education.

Objectives of the Study

The purpose of this paper is to describe and analyze integrated STEM curriculum that has been implemented with elementary students (ages 5-11) since 2010. Well-designed and tested STEM curriculum can help teachers' implementation that can lead to meaningful understanding of concepts (Stohlmann et al., 2014). This paper provides insights into what STEM concepts have been integrated. It serves to provide an update of what integrated STEM curriculum has been developed in the past decade. In particular, I focus on articles from teacher practitioner journals in my analysis. Prior reviews connected to integrated STEM curriculum have rarely included teacher practitioner journals. To get a more complete idea of what integrated STEM curriculum has been developed and implemented in classrooms, this work is needed. Having a clearer picture of what STEM concepts have been integrated is useful knowledge to guide future work.

Integrated STEM Education Theoretical Framework

The goal of integrated STEM education is to help learning be more connected, meaningful, and relevant to learners. Further, integrated STEM education is an approach that builds on natural connections between STEM subjects for the purpose of (a) furthering student understanding of each discipline by building on students' prior knowledge; (b) broadening student understanding of each discipline through exposure to socially relevant STEM contexts; and (c) making STEM disciplines and careers more accessible and intriguing for students (Wang, Moore, Roehrig, & Park, 2011). In general, integrated STEM education is an effort to combine at least two of the four disciplines of science, technology, engineering, and mathematics into a unit or lesson that is based on connections between the subjects and relevant contexts (Stohlmann, Moore, & Cramer, 2013). There are five main tenets for assessing or developing integrated STEM curriculum (Stohlmann et al., 2013). First, the context should be motivating, meaningful, and engaging for students. Second, there must be mathematics and/or science content as the main objectives of the curriculum. Third, the problems students work on should be open-ended with the teacher employing student-centered pedagogies including teacher as a facilitator and cooperative learning. Fourth, the curriculum should allow students to learn from failure and/or have the opportunity to redesign as they develop teamwork and communication skills. Finally, the curriculum should enable students to become more technology savvy through the use of technology or design of technology through the engineering design process. In terms of technology, I use the broad definition of technology. It does not only refer to electronic devices but to every object, system, or process that has been designed or modified to be useful to some person or a group of people.

Related Literature

There have been several reviews done in the past to describe integrated STEM education curriculum. Pang and Good (2000) reviewed studies integrating mathematics and science in the

1990s and concluded that the dominant approach at this time was science content receiving the main focus with mathematics in a supporting role. The researchers also noted that there is a need for evaluating the effectiveness of integrated approaches. Berlin and Lee (2005) conducted an analysis that surveyed the nature and number of documents related to integrated science and mathematics education published from 1901 to 2001. A total of 850 documents were included in the analysis with a large amount of the publications (389) in the 1990s. It was noted that science and mathematics integration was seen most in the elementary school grades compared to middle and high school. Becker and Park (2011) looked at studies from 1989 to 2009 on integrated STEM education that included empirical data to calculate effect sizes. Twenty-eight studies were identified, and it was found that integrating STEM subjects had a positive effect on students' achievement. Only quantitative studies that measured students' achievement were included in this meta-analysis. There was limited research on the effects of integrative approaches among STEM subjects on students' mathematics achievement though.

Taking a focus on engineering as the essential feature of integrated STEM, Diaz and Cox (2012) reviewed the literature on P–12 engineering education between 2001 and 2011. Fifty publications were identified and thirty-four of the studies used the rationale of improving mathematics and science achievement through engineering education interventions. The vast majority of the studies looked at teacher professional development or outreach activities with students done outside of the regular school setting. It was suggested that more work needs to look at integrated STEM education implemented during the regular school day.

I reviewed empirical studies done on integrated STEM education done at the K-12th grade level from 2008 to 2018. Integrated STEM education has an explicit focus on mathematics in integration. At the elementary level, there were 5 studies identified that showed mostly positive results along with the importance of well-structured curriculum. The results of the studies in the review provided support for the benefits of an integrated STEM education approach and further research in this area. I proposed three main ways in which to focus future research: mathematical modeling, engineering design challenges, and open-ended or game-based mathematics integrated with technology (Stohlmann, 2018).

The findings and conclusions of the prior research support that further research work is needed with integrated STEM education at the elementary grades level in the regular school setting. Recently, positive results have been found in integrating STEM subjects including the development of mathematical understanding, increased mathematical achievement, engagement, and interest in

STEM fields (Stohlmann, 2018). It is known that integrated STEM education research work is increasing (Li et al., 2020) but more needs to be known about the STEM topics that are being integrated (Stohlmann, 2018). Also, a better idea of what integrated STEM curriculum is being implemented during the regular school day is needed (Diaz & Cox, 2014). This paper provides further insights into the curriculum that has been developed and implemented in the past decade.

Methodology

The articles analyzed and described in this paper were identified by a close examination of two elementary education journals: *Science and Children* and *Teaching Children Mathematics*. Both of these journals are published by leading organizations in mathematics and science education. *Science and Children* is published by the National Science Teaching Association (NSTA). NSTA is the largest organization in the world committed to promoting excellence and innovation in science teaching and learning (NSTA, 2021). *Teaching Children Mathematics* is published by the National Council of Teachers of Mathematics (NCTM). NCTM is the world's largest mathematics education organization with the goal to advocate for high-quality mathematics teaching and learning for every student (NCTM, 2021). Both of these journals publish articles on classroom-tested integrated STEM education curriculum. Analyzing articles in these two journals provides a more accurate picture of the integrated STEM curriculum that has been developed and implemented in the regular school setting. In addition, many of these articles are authored by teachers and researchers collaborating in the classroom. This is beneficial as the curriculum developed and tested is analyzed by an instructional and research-based lens.

Articles published in these two journals between 2010 to March 2020 were analyzed to determine if the implementation of kindergarten-5th grade (ages 5-11) integrated STEM education curriculum was the focus of the article. At least two of the four disciplines of STEM had to be integrated through a relevant context. Every article was read through until it could be determined if the article included integrated STEM education curriculum. The articles with integrated STEM education curriculum implementation were then summarized with the following information: grade level of students, description of integrated STEM education curriculum, time or number of lessons to implement the curriculum, what STEM disciplines were integrated, and what STEM content was focused on. For the purposes of this paper, I focus just on the STEM content that was integrated into the activities. Due to page limits, references of the identified articles cannot be included, but the article references and more details on the curricular activities are available in Stohlmann (2020).

Results and Discussion

Overall, there were 85 articles identified with 21 of the articles in the NCTM journal and 64 of the articles in the NSTA journal. There were 24 articles at the K-2nd grade level and 61 at the 3rd-5th grade level. There were a variety of STEM concepts that were integrated into the curriculum. Table 1 has a summary of the STEM connections organized by the K-2nd grade band level and the 3rd-5th grade band level. The numbers in parentheses are the number of articles that included the content topic. Force and motion was a popular science topic. This has been noted in past research as a frequently covered topic (Guzey et al., 2014). There were other popular science topics though in this review including structure and properties of matter, energy, natural hazards/weather, and heat transfer.

Table 1: Summary of K-5th integrated STEM content integrations

K-2nd		**3rd-5th**	
Science		**Science**	
-Structure and properties of matter (10) -Force and motion (3) -Types of interactions (2) -Animal characteristics and habitats (2)	-Erosion -Nutrition -Recycling -Sound	-Force and motion (17) -Structure and properties of matter (11) -Energy (7) -Natural hazards/weather (7) -Heat transfer (4) -Water and water cycle (3) -Plants and animals (3) -Nutrition (2) -Sound (2) -Buoyancy (2)	-Systems (2) -Sustainability (2) -Light -Density -Fossils -Types of interactions -Biodiversity and humans -Chemical reaction -Structure and function
Technology		**Technology**	
-Design materials (22) -Robotics (2) -3D modeling program	-3D printer -App creator website	-Design materials (56) -3D modeling or coding program (5) -3D printer (4) -Video recordings (2)	-Simulation program -Data analysis program -Robotics -Design program
Engineering		**Engineering**	
-Design process (24) -Environmental engineering	-Mechanical engineering	-Design process (56) -Aerospace engineering (2) -Mechanical engineering -Materials engineering	-Biomimicry -Civil engineering -Green engineering
Mathematics		**Mathematics**	
	-Counting	-Measurement (32)	-Angles (3)

-Data collection and analysis (3) -Measurement (3) -Shapes (3) -Budget (2) -Operations (2)	-Symmetry -Representing and comparing whole numbers	-Budget (11) -Data collection and analysis (9) -Operations (8) -Proportional reasoning (3) -Measures of central tendency (3)	-Conversions (3) -Area (2) -Velocity (2) -Volume -Shapes

Almost all of the curriculum included the engineering design process. There were also a few instances of students learning more about specific fields of engineering. Engineering design is an integral part of integrated STEM education to ensure that natural connections can be made between subjects. To ensure a diverse well-prepared STEM workforce engineering education should become a required part of K-12 education.

The technology included materials used in the designs as well a few instances of robotics, 3D printers, and 3D modeling. Future work can look at ways of incorporating more coding and programming into integrated STEM curriculum. There is a movement for students in the elementary grades to have experiences with computer science concepts (Computer Science Teachers Association, 2018). Current technologies for programming are becoming more user-friendly, which can make it more likely for teachers to feel comfortable integrating programming

Data collection and analysis, measurement, and including a budget were the most often ways that mathematics was included. Prior research has noted that measurement and data analysis are frequent math topics for STEM integration (Guzey et al, 2014). There were a number of other mathematical topics included which shows progress in mathematics integration. The mathematics was often integrated though as an application of knowledge and not to develop mathematical knowledge. Internationally, mathematical modeling is an important research area (Stohlmann & Albarracín, 2016). Generally, mathematical modeling is connected with engineering education as students, express, test, and revise their ideas (English, 2009). Mathematical modeling is an excellent way for students to experience STEM education and develop their mathematical knowledge and thinking (Stohlmann et al., 2013). A focus on mathematical modeling provides more opportunities to integrate operations, measurement, and statistics (Stohlmann & Albarracín, 2016). In order to meaningfully include other mathematical topics, I have suggested further work on game-based mathematics integrated with technology as well. Game-based learning has great potential to engage students and integrate technology well to benefit mathematics learning (Stohlmann, 2017).

Implications

Past research has noted that science is often integrated more in integrated STEM education than mathematics (Becker & Park, 2011; Pang & Good, 2000). While more articles appeared in the science education journal, a total of 55 of the articles integrated mathematics. This was encouraging to see and shows progress towards including mathematics more in integrated STEM education. The large number of articles published across both journals in the last decade shows the continued growth of integrated STEM education.

The information in this paper can aid researchers and teachers who do work in integrated STEM education curriculum development through knowing what STEM content has been integrated. This can guide further work by knowing what STEM content topics show promise for integration and what topics may need further curriculum development. Meaningful STEM integration can lead to students having increased interest in mathematics and science as well as improved science and mathematical understanding. Integrated STEM education curriculum can provide teachers opportunities to meet standards from multiple disciplines which can save time and make learning more meaningful. It is important that integration of STEM concepts is done when there are natural connections between subjects so that the integration is not forced (Stohlmann et al., 2017).

STEM education can develop elementary students' curiosity, creativity, critical thinking, perseverance, teamwork, communication, and innovation capabilities (Hefty, 2014). Students can apply mathematics and science in meaningful and engaging contexts. The problem solving in these types of activities is similar to real-life in that there is more than one possible solution. The many benefits of integrated STEM education make it vital for continued curriculum development. The results of this paper demonstrate that work in this area is increasing and moving in the right direction.

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THE PROOF IS IN THE LESSON: INVESTIGATING LINKS BETWEEN PD, TEACHER PROFILES, AND MATH INSTRUCTION

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Abstract

This study provides an understanding about how teacher profiles might predict occurrences of ambitious teaching practices. We examined seven teachers for lesson behaviors that purport high-leverage teaching practices. This study employed the Instructional Quality Assessment (IQA) observation tool to rate videotaped lessons for Academic Rigor (AR) and Accountable Talk (AT). Ratings show task cognitive load (AR) was maintained during lesson implementation. Differences between ratings for AT during group discussions were not explained by teachers' content knowledge, teachers' self-reports of instructional routines, or frequency of task use.

Introduction

The Advancing Inquiry for Middle Mathematics Professional Development (AIMM PD) was designed to develop ambitious teaching practices which have been recognized in mathematics education research as effective (NCTM, 2014). We use the term ambitious teaching to describe an approach to teaching mathematics that necessitates the use of cognitively demanding tasks (CDTs) and close responsive questioning by teachers. "Ambitious teaching requires that teachers teach in response to what students do as they engage in problem-solving while holding students accountable to learning goals that include procedural fluency, strategic competence, adaptive reasoning, and productive dispositions (Kilpatrick et al., 2001; Lampert, 2001; Newman & Associates, 1996)" (Kazemi et al., 2009, p. 1). The AIMM PD for teachers in grades 5-9, focused on increasing teachers' use of cognitively demanding tasks, class discussion, and - questioning students to understand thinking. Project summary measures showed progress toward that goal. AIMM participants improved their content knowledge and shifted beliefs about teaching mathematics away from the transmission of ideas to mathematics as a connected set of ideas. However, teachers implemented only 25% of the tasks we presented to them during the PD and reported low percentages of time on problem-solving during lessons.

Objectives of Study

More understanding is needed about connections between content knowledge and beliefs to ambitious teaching behaviors during lessons (Blömeke et al., 2020). To understand the impact of the AIMM PD beyond our summary data, we undertook a second study that analyzed teacher behaviors during lessons. The AIMM Video Study addressed two questions: (1) How do participating teachers' behaviors during lessons reflect ambitious teaching? and (2) How do teacher behaviors during lessons compare to teachers' beliefs, self-reports of instructional practices, and content knowledge?

Background

Research supports problem solving, and student-centered instruction as essential to effective teaching (Polya, 1945; Schoenfeld, 2013). The AIMM PD was designed to support teachers' implementation of problem-solving, student-centered instruction and to engage in ambitious teaching. Teachers' beliefs and knowledge about mathematics teaching and learning provide the foundation for the teacher behaviors needed for ambitious teaching (Swan, 2006). Teachers find problem-solving, student-centered lessons challenging to implement for several reasons. Limited instructional time, limited teacher knowledge and confidence in problem-solving, a need for practical approaches and resources, and the diverse needs of students contribute to teachers' reluctance to deliver problem-solving-based instruction (Stein et al., 1996). The AIMM PD addressed these challenges by providing opportunities for teachers to deepen content knowledge and implement problem-solving lessons.

Cognitively demanding tasks (CDTs) ask students to go beyond the application of algorithms or procedures and are posed in a way that elicit authentic problem-solving behaviors (Stein et al., 1996). As the cognitive demand of classroom tasks increases, so does student learning (Boaler & Staples, 2008). As an example of a CDT consider the following: "Twenty motorcycles and cars are in the parking lot. There is a total of 50 wheels. Exactly how many motorcycles and cars are in the lot?" For someone with a strong algebra background, this is easily solved, but for a typical 6th or 7th grader, it is a CDT. Maintaining cognitive demand requires teachers to listen to and observe students and offer feedback through questioning and probing, rather than showing how to solve the problem. The AIMM PD was designed to support teachers who lack experience implementing these tasks by developing ambitious teaching practices.

Principles to Actions (NCTM, 2014) states that teachers should "continually monitor and respond to their students' progress through formal and informal means, including…effective questioning and classroom discussion, [and] conducting interviews with individual students" (p. 94). Getting students to think and fostering an ability to solve problems are key goals for teachers (O'Connell, 2007). Through questioning, teachers can monitor and adjust teaching and instruction to help students grow in their mathematical abilities. In the example problem above, a teacher's questioning patterns might involve asking what the child has already done, asking the student to show their thinking using multiple representations, and if the student is struggling to begin, asking them to imagine the lot full of cars and motorcycles, or to re-read the problem, or to model the problem. Questioning during whole group sharing of problem solutions can highlight connections between strategies and ideas so all students have access to important mathematics.

Methodology

The AIMM PD project (2018-2020) included face-to-face summer and follow-up workshops and independent activities, such as recording lessons, collecting and analyzing student data, and reflections on the tasks. The PD provided a specific, in-depth exploration of 36 CDTs from the areas of geometry, algebra, proportions, and fractions. Eighty-six teachers participated in both years of the AIMM PD project. Measures of AIMM teachers' content knowledge, beliefs, and practices showed that teachers improved in all areas.

The AIMM Video study (AIMM-V) was designed to compare self-reported measures of teachers' content knowledge, beliefs, and instruction obtained from the AIMM PD project to taped lessons using the IQA lesson rating system. We invited 14 teachers to join the AIMM Video study because they completed all the assigned tasks and attended over 90 percent of PD sessions. We believed these teachers were likely to implement the ambitious teaching practices they learned during the AIMM PD because of their level of participation. Seven agreed to participate. After principals approved the request, we obtained parental consent and student assent for permission to videotape. Six of the seven teachers submitted two video-recorded lessons for a total of 13 lessons. Teachers were encouraged to use the CDTs they had learned about during AIMM PD. AIMM-V teachers' lessons were videotaped in the Fall of 2019.

We selected the Instructional Quality Assessment (IQA) (Boston & Candela, 2018) because it was designed to identify similar behaviors focused on during the PD and hoped to see in the lessons. The IQA employs two rubrics: Academic Rigor (AR) and Accountable Talk (AT). AR has five lesson dimensions: the potential of the task, implementation of the task, whole group discussion, questioning during discussion, and residue (likelihood of meaningful learning). AT rates teacher and student talk along four dimensions: teacher and student linking and teacher and student press. Linking occurs when teachers or students note the similarities or differences between the two approaches. Press occurs when a teacher prompts or students volunteer evidence or justification thinking, Accountable Talk moves are ranked on a scale from 0 to 4 depending on their frequency.

Authors participated in an IQA instrument training led by Boston, and rated one lesson together, aiming for evidence-based consensus. To ensure inter-rater reliability, we rated the remaining 12 lessons individually and met to confer and discuss any differences. Discrepancies were resolved by focusing on evidence for ratings and consulting the IQA manual for clarification. There were few disagreements between raters which were resolved without difficulty. One change was made to the rubric. The original rubric lists Questioning in Academic Rigor, and the rating is limited to questioning during whole group discussion. We added questioning (small q on the table) to rate the questioning we observed when teachers were working with students as they were solving problems. Finally, to consider each teacher's best effort, we selected the lesson with the highest ratings for each dimension for each teacher (Boston & Candela, 2018) for our comparison.

Teacher profile data collected at the end of the AIMM PD project in the Spring of 2020 includes measures of content knowledge, belief orientations about mathematics teaching and learning, instructional practice beliefs, and self-reported teaching routines and math task use. The Content Knowledge (CK) survey featured items from the Learning Mathematics for Teaching (LMT) Project (Hill et al 2004) for algebra, geometry, fractions, and proportions. LMT items measure content knowledge in the context of teaching. An item assessing teachers' algebraic knowledge might ask teachers to identify correct equations matching descriptions of student strategies, or ask teachers to identify a student's informal description of an algebraic relationship (Hill et al., 2004). These item types are considered reflective of content knowledge for teaching, not pedagogy because no pedagogical decisions are being assessed.

Belief Orientations (BO)were assessed using the beliefs questionnaire by Swan (2006). Statements aligning to three orientation types are presented and teachers weigh the importance of each statement. Transmissionist oriented statements are characterized by telling students what to do to solve problems (teaching by transmission); Discovery-oriented belief statements indicate that math is best learned by how math works by exploring and experimenting, and; Connectionist orientated statements indicate the belief that math is best learned as a set of connected ideas. Teachers weigh each belief statement for three contexts: teaching, learning, and mathematics. Overall belief orientation is assessed for all three beliefs for a ternary, or three-part score. Survey of instructional practice (IP) (Swan, 2006) asked teachers to mark statements on a 5-point scale from almost never to almost always. Statements reflected student (ST) or teacher-centered (TC) instructional methods. The survey for Teaching Routines (TR) asked teachers to say give a percentage for class time spent presenting problems (L), students working problems (E), and discussing problem solutions (D). Teachers could answer 'other' to account for activities such as homework checking and other math tasks, so percentages do not sum to 100%. AIMM PD teachers also reported the number of AIMM PD Math Tasks (MT) they used during lessons.

Results and Discussion

Table 1 compares our AIMM-V teachers to all teachers in the AIMM PD in terms of total PD hours and five project measures. AIMM-V teachers performed above the mean of the AIMM PD group in amount of PD hours, and content knowledge. Video teachers' belief orientations were either Connectionist (4) or Discovery (3). The AIMM-V teachers self-reported instructional practices and teaching routines were similar to the AIMM PD teachers. AIMM Video teachers' agreements were higher for both SC and TC. AIMM-V teachers reported offering problems more often than the overall group (about 1 more problem on average).

Table 1

Teacher Profiles

	Grade Level	PD Hrs	CK (%)	BO	IP		TR (% time)			MT (of 36)	Rating AR/AT
				B	TC	SC	L	E	D		
Mean (S.D.)		150 (49)	57 (16)	-	2.7	3.4	18	33	27	8.6 (4.7)	
V-TCHR Mean		161	67		2.8	3.3	15	36	24	9.4	
Ms. T	8th	155	50	D	3.5	3.6	10	50	10	7	H/H
Mr. D	7th	166	52	D	2.3	3.0	20	50	20	10	H/H
Ms. F	9th	168	64	C	2.8	3.7	10	30	30	8	H/H
Ms. N	7th	157	72	C	2.7	3.0	15	30	40	9	L/L
Ms. B	9th	119	74	D	2.8	2.6	10	20	30	14	H/L
Ms. D	7th	155	74	C	3.1	3.6	30	30	20	6	H/L
Ms. J	9th	157	82	C	2.2	3.8	10	40	20	12	H/H

The last column in Table 1 shows the AR and AT levels for each teacher. If dimension ratings within the rubric were mostly 3 or 4 the level was High (H), if the ratings were mostly 1 or 2 the level is Low (L). Table 2 shows detailed results from the IQA lesson ratings. The AIMM-V teachers consistently scored high AR (3 or 4) for Task Potential, Task Implementation, and Questioning students as they were working (small q). Accountable Talk behaviors during whole-class discussions were less consistent between teachers' lessons. There was only a single rating of 4 for any dimension within AT, and 11 scores were low (1 or 2), meaning few instances of teachers or students pressing further on ideas or linking between ideas were observed.

Table 2

Lesson Ratings by Teacher

Teacher	Ms. N	Ms. D	Ms. B	Mr. D	Ms. F	Ms. J	Ms. T
Academic Rigor (AR)							
Task Potential	3	3	4	3	4	4	4
Task Implementation	2	4	3	3	3	3	4
Discussion	2	3	1	4	3	3	3
Questioning (q)	-	4	4	-	3	4	4
Questioning (Q)	2	2	-	3	3	3	3
AR Level	L	H	H	H	H	H	H
Accountable Talk (AT)							
Teacher Linking	2	2	-	3	3	3	3
Student Linking	2	1	-	2	2	2	2
Teacher Press	3	2	-	3	3	3	4
Student Providing	2	2	-	3	3	3	3
AT Level	L	L	L	H	H	H	H

Lessons from Mr. D and Ms. T received high ratings for Academic Rigor (AR) but had content knowledge scores of 50% and 52%, whereas Ms. N. who had the highest content score received the lowest rating for AR indicating that content knowledge is not enough evidence to predict ambitious teaching behaviors. Similar findings occurred when examining Accountable Talk.

Teachers' profile measures inconsistently predicted which lessons would be rated as High (3 or 4) or Low (1 or 2) for Accountable Talk, as well. For example, Mr. D.'s lesson rated as high level in Accountable Talk measures, while Ms. D. and Ms. N who scored 74 and 72 respectively had lessons rated as low for Accountable Talk. In neither lesson did Ms. B ask questions of students or make linking remarks about the strategies she shared at the end of the lesson so AT could not be rated. However, while introducing the task and with small groups and individual students, she maintained the cognitive load (task implementation) and asked high-level questions. Two teachers did not receive a rating for questioning (small q) during the lesson. Mr. C had a class of three students, and there was no differentiation between a whole group discussion and a small group discussion. Ms. N's lesson was conducted entirely as a whole group discussion. She presented the problem in segments at the front of the room while students were working, and held a series of short, whole-group discussions as each segment was completed.

AIMM-V teachers engaged students in questioning and connecting while students worked on the tasks (*Questioning (q)* on Table 2). Teachers may have planned to have a discussion, but there was too little time to hold a substantive whole-class discussion. For example, Ms. B. presented different strategies from students herself at the end of the lesson and did not ask questions or make connections during this short time due to the ringing of the dismissal bell. Questioning during small group or individual interactions showed teachers could link and press but teachers were not able to demonstrate these behaviors during whole group discussions. Ms. T was the exception. On the second day of her lesson, we observed students working together to create posters of their work and placing the posters on the board next to each other. Students each explained their approaches, and Ms. T was able to use both what she observed while they were working and other students' work on the posters to link thinking to big ideas and to each other (*teacher linking*), and ask students to do more (*teacher press*). Placing posters and students at the front of the room prompted students to ask questions of each other (*student press* and *student linking*).

Implications

Analyses of teachers' videotaped lessons illustrate connections between teacher profile measures and ambitious teaching behaviors during lessons. Teacher content knowledge has been greatly emphasized in mathematics education research as a key characteristic. However, for our seven teachers, content knowledge did not predict behaviors such as teacher press or linking during discussion. Connectionist and Discovery belief orientations have been found to align with student-centered practices, while teachers holding Transmissionist beliefs are associated with teacher-centered practices (Polly et al., 2013). The AIMM-V teachers' Connectionist/Discovery belief orientations align with teachers' maintenance of cognitive demand (6 of 7 lessons) which is reflected in the higher ratings for Academic Rigor. These orientations, along with high ratings for Academic

Rigor for most lessons suggest that the AIMM PD contributed positively to teachers' implementation of cognitively demanding tasks during lessons. Ms. D. demonstrated high-level questioning strategies when interacting with students during the lesson (small *q)*, which indicates she has the skills to press for student thinking and make connections. Ms. D.'s case has implications for teaching and learning. The ideas shared and discussed with a few students while they are solving problems need to be shared during the whole group discussion so that all students in the class have access to the ideas. Professional development leaders can do more to highlight that effective questioning and probing is just as important (and maybe more) during whole group discussion as it is when closely interacting with students as they work. The importance here is key if teachers in problem solving lessons want to increase equity since students who were not a part of the small group discussions in which high-level interactions were occurring might miss out on important mathematics. The AIMM Video study identified specific ambitious teaching practices during lessons, which highlighted that more attention to whole-class discussion and accountable talk moves of teacher press and linking is needed during mathematics professional development.

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Acknowledgements

We thank the Greater Texas Foundation for funding this work.

EXPLORING PUBLIC SCHOOLS' APPROACHES TO STEM: A PILOT STUDY

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Abstract

This pilot study explores approaches to integrating STEM in K-8 schools. Semi-structured interviews were conducted to understand how principals and teachers at a traditional public school and a STEM school conceive and implement STEM. Findings indicate schools value providing access to STEM, but differ significantly in the role of community, the depth of learning, and methods of assessment. These findings suggest more research is needed to explore implications for equitable teaching and learning of STEM.

Keywords: Elementary STEM Education, Equitable Teaching and Learning, Assessment

Introduction

Science, technology, engineering, and mathematics (STEM) education is positioned both as vital for people to function in a rapidly changing, technological world (International Technology and Engineering Educators Association [ITEEA], 2020; Mohr-Schroeder et al., 2020) and for national security and workforce needs (National Science Board, 2015; Maiorca et al., 2021). Thus, there is increased interest in STEM and incorporating STEM into schools. Students who engage in high-quality STEM learning experiences recognize how core content can be applied and extended in more authentic ways (Roberts et al., 2018). In recent years, schools have incorporated STEM programs as a series of courses, but limited research examines the benefits of STEM specific schools (Patel et al., 2019). Although STEM programs and STEM schools are becoming more popular, there is limited and often conflicting research focused on the benefits of STEM focused schools (Patel et al., 2019). For example, the National Research Council (2011) suggested students in STEM schools and programs engage in more flexible and adaptable learning than students in traditional public schools; however, Kogo-Masila (2017) did not find any differences in achievement between STEM schools and traditional public schools. This pilot study seeks to address the gap in the literature and investigate the divergent results by exploring how principals and teachers approach to STEM in school settings.

Objectives of the Study

The purpose of this pilot study was to explore major curricular and pedagogical differences between STEM schools and traditional public schools. We distinguish between STEM schools, defined as schools with integrated STEM through a whole school agreement (Karp et al., 2016; Chiu et al., 2015), and traditional public schools, defined as traditional public schools that have a STEM course or series of courses as specials or electives. The research question is: How do STEM schools differ from traditional public schools?

Theoretical Framework and Related Literature

Jackson et al.'s (2021) equity-oriented framework for K-12 STEM literacy framed our approach for the study. This framework recognizes each and every student must have opportunity and access to high-quality integrated STEM learning experiences that empower students to see the applicability of STEM content. Participating in these high-quality integrated STEM learning experiences helps students develop positive STEM dispositions, STEM identities, and critical STEM skills such as critical thinking and problem solving which can lead them to disrupt systems of oppression and become societal change agents (Jackson et al., 2021). High-quality integrated STEM learning experiences allow students to apply discipline-specific content and practices while solving rigorous, authentic problems (Roberts et al., 2019). This often takes the form of inquiry approaches of instruction (Ballenger, 2005) and the use of hands-on activities and intentional discourse strategies to utilize student thinking (Palinscar et al., 2000). As students solve rigorous, authentic problems, students engage in the content practices (e.g., Standards for Mathematical Practice, Technology and Engineering Practices) and see the utility and applicability of the individual disciplines as they use content knowledge to design solutions to problems (Jackson et al., 2021; Roberts et al., 2018). This helps students to develop positive STEM dispositions, which includes students' attitudes, interests, and motivation toward STEM topics (Kilpatrick et al., 2001). Through consistent engagement in these rigorous, supportive environments, students can develop positive STEM identities that empower them to engage in STEM as they have agency in designing solutions to real world problems (Jackson et al., 2021). How teachers and administrators design, facilitate, and support the learning experiences are critical to the quality of the learning experience and the cognitive and affective outcomes students develop from those experiences. Thus, it is critical to explore how teachers and administrators approach to STEM in school settings.

Methodology

We contacted eight schools in northwest Ohio to identify interest in having one principal and one teacher from each school participate in this study. Purposive sampling was used to select schools (Creswell, 2014) meeting two criteria: (1) all schools were public schools with a STEM component; and (2) divergent school demographics (e.g., urban and suburban) were targeted. As this pilot study occurred during the Covid-19 pandemic, two schools agreed to participate which gave us four (4) total participants. One school is an urban, K-8 school that has adopted a school-wide approach to integrated STEM. We call this school Giraffe K-8 in this paper. Giraffe K-8 has approximately 350 students with 38% being African American, 25% being white, 22% being Latinx, 15% being other. 82% of the students at Giraffe K-8 receive free/reduced lunch. The principal identifies as a middle-aged white male and the seventh-grade mathematics teacher identifies as a middle-aged white female. The other school is a suburban, K-5 school that uses a bi-weekly elective approach to STEM. We call this school Bovine Elementary in this paper. Bovine Elementary has approximately 600 students with 79% being white, 8% being Latinx, 6% being Asian, 2% being African American, and 5% being other. 8% of the students at Bovine Elementary receive free/reduced lunch. The principal identifies as a middle-aged white male and the STEM teacher, who is shared with another school, identifies as a middle-aged white female. All participants have more than 5 years of teaching and/or leadership experience.

Data collection consisted of semi-structured interviews with the principal and one teacher of the two schools that agreed to participate. Interviews were conducted in Spring 2021 via Zoom due to Covid-19 restrictions and lasted for 45-60 minutes. The principals' questions included asking them to explain the pedagogies used within the school if they think their school has a successful STEM curriculum, their priorities and values in the school, and how student demographics influence the pedagogical decisions used in the school. The teachers' questions included asking them to explain their STEM curriculum and pedagogy, inquiring into the effectiveness of their approach to STEM, if they would change anything, if they have the resources they need, and how students are most engaged. Classroom observations were planned but could not be conducted because of the Covid-19 pandemic.

All interviews were transcribed verbatim. Data analysis consisted of first cycle coding (Saldaña, 2016) that used descriptive coding (Miles et al., 2014). The first author used open coding to code the transcripts. The authors discussed the coding and disagreements to reach a consensus. Next, pattern coding was used to group and label similarly coded data as a way to attribute meaning (Saldaña, 2016) and identify themes. Pattern coding helped identify common themes and divergent cases by looking across categories for underlying patterns (Delamont, 1992). The authors discussed the themes and supporting data for clarity and content validity.

Results and Discussion

Three themes emerged from the data: access to STEM, community, and assessment. Both Bovine Elementary and Giraffe K-8 emphasized the importance of giving students access to STEM learning experiences. When asked about the school's STEM curriculum, the Bovine Principal said, "I wish it was more… but just seeing the lack of consistency in STEM… bothers me" (Bovine Principal Interview). Bovine's teacher explained that she "only sees students 22 times a year" and "at one point there was a class that I hadn't seen in four months" (Bovine Teacher Interview). The teachers and principal at Bovine Elementary want to give students more access to STEM learning because "it's an avenue for some of our kids and it is… their needs and desires" (Bovine Principal Interview). In recent years, Giraffe K-8 sought a way to implement high-quality learning experiences as the school was classified as low performing based on standardized test scores, particularly in reading and math. They transitioned to a STEM school "to put a program in place that… could reengage students" and hopefully improve test scores (Giraffe K-8 Principal Interview).

Although both schools recognized the need for access to more STEM, each school approached STEM learning in drastically different ways. For example, Giraffe K-8 prioritized extended inquiry that valued students' lived experiences and emphasized the applicability of disciplinary content. The Giraffe K-8 teacher noted the importance of using students' backgrounds and prior knowledge when creating a successful lesson. "I think, doing it the way I'm teaching now and applying it to things that they know and things that they're going to need to know [is important]" (Giraffe K-8 Teacher Interview). The biggest questions asked in her classroom are "What do I need to know this for?... How is this going to help me in the future?" (Giraffe K-8 Teacher Interview). To answer those questions "…I try to teach them things and [explain] where you'll use this and… do [it] in class so that you can see that" (Giraffe K-8 Teacher Interview). The Giraffe K-8 teacher explained, "I mean honestly I prefer STEM teaching because I think that… [in regard to] real – world application to the rest of their lives, STEM is the way to go" (Giraffe K-8 Teacher Interview). By using students' backgrounds and engaging them in applications of content, the Giraffe K-8 teacher made the learning more relevant.

Bovine Elementary took a different approach. They emphasized access to using technology and quick activities. The STEM teacher said, "technology is a pretty big priority and it's always been… an emphasis in this program" (Bovine Teacher Interview). The teacher noted how it is difficult "to hit… science, technology, engineering, and math all in one… lesson," so she focuses on "just basic knowledge of just what STEM concepts are" (Bovine Teacher Interview). For example, Kindergarten students can build a letter that goes along with the book *Chicka Chicka Boom Boom*. The teacher recognized the limitations of doing quick activities as she said, "I cannot dig deeply" (Bovine Teacher Interview). Much of the problem lies in staffing and facility shortcomings as the school district did not provide adequate STEM teacher staffing and adequate STEM lab space. However, this shortcoming impacts the quality of the STEM learning experiences students have. Thus, Bovine Elementary students do not receive the more rigorous STEM learning experiences that require a real-world application of the content as students of Giraffe K-8 do.

A second theme that emerged was the importance of community. Giraffe K-8 values community in and out of the classroom. "Students are expected to reach out and get in touch with real experts in the field" (Giraffe K-8 Principal Interview). Giraffe K-8 partnered with the local zoo and manufacturing company to "build that community feeling [by] bringing some of these neighborhood experts in and working with our students" (Giraffe K-8 Principal Interview). While Giraffe K-8 focused on community learning and experiences, they also invited parents into the school to help form community connections. The school hosted open houses, parent-teacher conferences, and presentations for parents and community members. Their efforts have resulted in "the numbers that we're getting for parent-teacher conferences, presentations… those numbers are all going up" (Giraffe K-8 Principal Interview). Along with parent involvement, "Our student… and staff absentee rate has dropped significantly as well" and "over the past three years we are getting more out–of–district requests" (Giraffe K-8 Principal Interview).

Bovine Elementary's approach to community was transactional. The principal viewed relationships as a currency to use in different conversations. He explained, "I think if you build a relationship with anybody it makes you know contentious conversations easier, [so] I challenge each of our teams to make at least two positive contacts… [because it] really lays the foundation" for future work (Bovine Principal Interview). Other than the need to build up goodwill for contentious conversations, Bovine's principal also noted the importance of the community's expectations. He described Bovine Elementary as "a fantastic … community school. The expectations and the drive to be excellent are there with our community" (Bovine Principal Interview). Unlike Giraffe K-8, Bovine Elementary's principal did not focus on partnerships with the community or community involvement; instead, the community's expectations to be high performing were emphasized.

Finally, the last theme that emerged was the role of assessment in STEM. Much like the divergence in community, Giraffe K-8 and Bovine Elementary had different takes on the role assessment plays in their approach to STEM. Giraffe K-8's teacher and principal highlighted the lack of standardized testing as a positive development during the Covid-19 pandemic. As the teacher explained, "you can't give a standardized test that will show what a stem school is learning" (Giraffe K-8 Teacher Interview). The principal emphasized the importance of using project-based learning to have students "show what they've learned and demonstrated their learning rather than answering questions on a test" (Giraffe K-8 Principal Interview). The principal and teacher not only view this as more an authentic assessment, but they also view it as a better-suited form of assessment for their students. The students at Giraffe K-8 have traditionally not met state expectations based on standardized test scores; however, the principal believes the students "are most ready for project-based learning because their whole life is dealing with situations that they don't have control over" (Giraffe K-8 Principal Interview). Thus, they are natural and creative problem solvers. Throughout their discussions on assessment, both the principal and teacher recognized the systemic barriers standardized testing reinforced for Giraffe K-8's students and advocated for a better system.

Bovine Elementary did not lament the relief from standardized testing due to the Covid-19 pandemic; instead, the STEM teacher wanted specific standards and assessments for STEM so that they could uphold the community's expectations for excellence. The STEM teacher noted, "it would be nice to just have set goals" because "we have no official curriculum whatsoever… we do not have assessments" (Bovine Elementary Teacher Interview). This lack of clear expectations and performance measures was in contrast to their general education approach where "if you walked into a third-grade classroom across the district they know that within this week we're on fractions"

(Bovine Elementary Teacher Interview). The lack of direction was not viewed as an opportunity; instead, it added stress and did not match with the school's value of upholding the community's expectation for excellence as measured by test scores.

These three themes show commonalities and stark differences in how these schools approached STEM. Giraffe K-8 embraced the open nature of STEM to engage their students in rigorous, high-quality STEM learning experiences that emphasized the applicability of content knowledge. The lack of standardized testing was viewed as a way to accurately measure students' knowledge and disrupt a system that positions the school as deficient. This is reflective of the approach described in the equity-oriented framework for STEM literacy (Jackson et al., 2021) and in line with other successful approaches to STEM (e.g., Roberts et al., 2018; Roberts et al., 2019). Bovine Elementary expressed a desire for STEM but lamented their current inability to demonstrate excellence through a system that relies on standardized testing to position them as excellent. As there is a values conflict, Bovine Elementary's district did not provide the resources (e.g., staff, facilities) to engage in more rigorous STEM explorations at the elementary level.

The findings reinforce the divergence within the literature. The teachers and principals at Giraffe K-8 and Bovine Elementary support their approaches to STEM and articulated the benefits of their STEM programs. However, the reported benefits conflict as Patel et al., (2019) also found. Some of the conflicts are due to divergent values, as Giraffe K-8's principal and teacher articulated the benefits of their program in terms of critical thinking, flexibility, and problem solving, similar to the findings of the National Research Council's 2011 report. Bovine Elementary valued achievement on standardized tests which are not currently available for integrated STEM. These value differences are reflective of the lack of an agreed-upon approach to and purpose for STEM education in the research literature and at the policy level (Moore et al., 2020).

Implications

Based on the findings of this pilot study there is a clear need for more work on school-based STEM models at the elementary level, which has not been thoroughly explored by the field (Hansen, 2013). The divergent approaches taken by Giraffe K-8 and Bovine Elementary have implications for how students experience STEM. The approach taken by Giraffe K-8 aligns with the equity-oriented conceptual framework for STEM literacy (Jackson et al., 2021) as it seeks to leverage student and community knowledge to engage in high-quality STEM learning experiences that apply content knowledge and attempt to disrupt systems of oppression; conversely, Bovine Elementary benefits from the status quo and, as a result, focuses on exposing students to STEM basics as there is no standardized assessment to position them as excellent. Thus, not only is there a need for research on elementary school approaches to STEM, but also on the implications for equitable teaching and learning of STEM, including the impact different forms of assessment have on students' and teachers' willingness to participate in STEM. Finally, the original research design for this pilot study was more robust but could not be enacted due to restrictions from the Covid-19 pandemic; thus, future research should have more participants and should rely on multiple sources of data including classroom observations and conversations with more teachers, students, and parents.

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Acknowledgements

This project was funded by the Fahle Scholarship in the College of Education and Human Development at Bowling Green State University for undergraduate student research in education.

HUMANIZING GRADUATE MATHEMATICS EDUCATION: INSTRUCTOR AND STUDENT PERCEPTIONS

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Abstract

In a state hostile to anti-racist and culturally sustaining pedagogies, this paper examines the experiences of two students and two instructors during a two courses sequence focused on disrupting dominant narratives in mathematics education. Using self-study techniques, we ask what experiences were most meaningful to students, how those experiences aligned with instructor intentions, and how those experiences influenced the students as teachers, scholars, and researchers. We find that while specific experiences motivated the students to change teaching practices, the sum of the year-long experience also had a significant impact on their identities as researchers.

Keywords: graduate mathematics education, anti-racist, culturally sustaining, social justice,

Introduction

In early 2021, state-level bills pushing back against anti-racist teaching were proposed in several states. The state in which the authors learn, and work is one to have passed such a bill. While the passage of this bill has attracted national attention, it represents only a minor shift. State lawmakers have made explicit the systems of resistance and hostility towards anti-racist and culturally sustaining pedagogies that have persisted in the state for years. For mathematics educators, these systems seek to simultaneously position mathematics as universal (thereby not requiring culturally sustaining pedagogies) and apolitical (thereby irrelevant to discussions of systemic racism).

Because graduate students in mathematics education are often current or former classroom teachers, they are products of these inequitable systems. Yet, the understanding and use of anti-racist and culturally sustaining pedagogies are critical for future mathematics educators. AMTE's Standards for Preparing Teachers of Mathematics (2017) requires that mathematics teacher education programs provide "opportunities for candidates to learn about the social, historical, political, and institutional contexts that affect mathematics teaching and learning," and NCTM (2014) asserts that mathematics educators should address "factors that contribute to differential outcomes among groups of students." Thus, it is imperative that future mathematics educators be familiar with political and cultural histories that have shaped inequitable mathematics education systems and critical of the practices and structures that allow these inequitable systems to propagate.

Theoretical Frame and Purpose

We adopt a view of mathematics as a human enterprise shaped by the thoughts, beliefs, identities, and cultures of those who engage in mathematics. Mathematics includes activities and experiences; it encompasses thinking, strategies, mistakes, corrections, revisions, rethinking, and reifying thought through social interaction. It is therefore a lived experience shared by teachers and students who work together as they define the shape of the work daily. When mathematics teachers adopt culturally sustaining and anti-racist pedagogies, all students benefit from their peers' diverse thinking and experiences as they 'do mathematics' together.

However, the ways in which traditional mathematics education supports inequitable systems of education are often unseen unless educators consciously seek to uncover them. Yet, uncovering these systems may not suffice to engage educators in deconstructing them or developing more equitable systems. In this self-study, we examine our experiences as teachers and learners in a two-course graduate sequence designed to uncover inequities in educational systems while developing an understanding of mathematics as a human endeavor. We ask 1. How did the instructors intend to uncover inequities in mathematics or mathematics education? 2. How did two graduate students develop an understanding of these inequities, and how did they respond?

Literature Related to Social Justice Mathematics

Social justice mathematics education aims to expose students to injustice, invoke critical thinking, and empower equitable change for society. However, teaching social justice through a mathematics curriculum has challenged both students and educators. With little to no support in a prescribed curriculum, classroom teachers pursue this endeavor independently through readings, peer support, and university courses. This has resulted in a focus on "safe" topics, like food deserts and water security, while topics that have not been well received by administration, families, and other stakeholders are left unexplored. These topics include examining systems of oppression and the role of racism in social justice. For example, mass incarceration in America has grown to overwhelming numbers since the 1980s. The United States imprisons more people globally than any other country, with over 2.4 billion behind bars, 60% of whom are people of color (Prison Policy Initiative, 2020). Crime, violence, and imprisonment involve statistics and tangible mathematics that interest students, impact their lives, and meets the NCTM expectation of teaching real-life mathematics (NCTM, 2000). When examining mass incarceration data, the racial disparities are glaringly evident and necessitate conversations about race, the war on drugs, and the caste system created by imprisonment (Alexander, 2012). The Black Lives Matter movement and recent police violence, examining incarceration, the justice system, and economic impact through mathematical calculations allow students to think critically and form their independent ideas. Unfortunately, many teachers are hesitant to engage students in such lessons due to perceived controversy.

The emotions invoked by social justice lessons can surface in the classroom and are usually felt by both the teacher and the students. Therefore, the lessons should be taught in safe spaces where students can express their opinions based on the data and research. However, teachers must use caution not to appear to force their personal beliefs and agendas upon the students (Gregson, 2013). Social Justice courses and professional development can help teachers navigate these spaces by providing tools, training, and educational materials. Understanding how to be unbiased and compassionate when presenting content and participating in discussions is imperative to students' critical thinking development and should be developed in teacher preparation programs.

Literature Related to the History of Mathematics

Perceptions of mathematics shape our understanding of the subject and the development of curriculum and influence research into the field (Dossey, 1992). A popular view of mathematics as a school subject is absolute and truth (Ernest, 1992). In mathematics classrooms, students are often taught mathematics by introducing formulas, focusing on correct answers, and prescribed ways to solve problems. This idea of the nature of mathematics as a static subject is contrary to the reality that mathematics is a human activity that is personally constructed. Including the history of mathematics in the general instruction of mathematics allows for a shift in understanding of the subject from one of absolute truth that exists in the universe to one of mathematics as a subject that is done and created by people.

Teachers' beliefs about mathematics influence how mathematics is taught and the message that students receive about the subject and its nature (Dossey, 1992). In many mathematics classrooms, students are given routine tasks that require procedures to find a correct answer (Ernest, 1992). However, when mathematics is seen as a human endeavor, the focus shifts from knowing math to doing mathematics. The NCTM recommends focusing on a personal construction of mathematics in their Principles and Standards for School Mathematics (NCTM, 2000). The history of mathematics helps determine what mathematics is and how it functions within a society (Lerman, 1990). When the history of mathematics is included in the classroom, it is placed into a cultural context that allows math to be associated with social practices that are the basis for the development of the subject and opens the door to culturally sustaining mathematics pedagogy (Ernest, 1992).

Much of the history of math is excluded from the curriculum, and that which is known tends to focus on the contributions of white men within the field. However, there is a vast history within all cultures of the development of mathematics. From the development of ancient number systems to the contributions of women of color at NASA, there are many opportunities to share how a diverse group of people and cultures have contributed to the body of mathematics. Not only is this relevant to the understanding of mathematics as a human process but in decentering white voices in the history of the subject (Ali, 2008). University course experiences with cultural exploration into mathematics contributions alter teachers' perspectives to better understand the history and learn how to include it in their teaching practice.

Methodology

This study employed a case study approach (Merriam, 2009) with interviews of four participants. The case is bounded by the experiences of instructors and students in two courses taught in the 2019-2020 school year: one focused on investigating social justice issues through mathematics and the second focused on the history of mathematics. The purpose of this study was to attend to the stories of the experiences within the coursework (i.e., intrinsic purpose) and to consider the implications of those experiences for both the instructors and students in the courses (i.e., instrumental purpose) (Stake, 2000). This case study is informed by self-study methods used in education (Coia & Taylor, 2009) because the researchers were instructors and students engaged in the courses. To better evaluate our work as teachers and learners, we engaged in formal self-study to confront our own words as stories on paper.

The participants in this self-study included two mathematics educators and two doctoral students in mathematics. The first participant was a white, female, cisgender Assistant Professor of mathematics education. The second participant was a white, female, cisgender Professor of mathematics education. Both are members of a curriculum and instruction department in a college of education and instructed one of the two courses under study. The final two participants are students in the doctoral program of the same department. Participant three was a Native American, female, cisgender elementary mathematics teacher, and participant four was a white, cisgender secondary mathematics and engineering instructor. Each participant engaged in a semi-structured interview about their experiences in the courses. Each instructor taught one course, while the doctoral students engaged in both. Open-ended questions were designed to investigate the learning experiences perceived to be the most meaningful to each participant, how these experiences uncovered inequitable systems, and how the participating students responded. Interviews were audio and visual recorded via Zoom and then transcribed verbatim. Each transcription was then open coded by two researchers. After open coding, researchers met to compare codes and address disparities codes. Once researchers reached an agreement on the codes, the codes were sent to the remaining researchers for review. Themes in the codes were then established across the two instructor participants, the two student participants, and finally, across all four participants.

Participant	Quote	Code	Theme
Instructor 2	I wanted to help students navigate and deconstruct indoctrination and identify their personal accountability. Students need to be receptive to new information and views and develop critical questioning perspectives.	Disrupt current practices and beliefs	Disrupt Current Narrativ e
Instructor 1	I also wanted to disrupt the notion of math and science as being white subjects.	Disrupt the idea of math/sci as white subjects	Disrupt Current Narrativ e

Table 1 Example of the Methodology

Results and Discussion

Several themes emerged from the interviews of the professors. First, the professors used specific teaching practices with the intent to develop classroom cultures and meet the needs of diverse learners. In both courses, assignments included autonomy and choice, "to leave those really open for personal interest and for the level of mathematics." This flexibility allowed graduate students to pursue their research interests and make meaning of the information. Both also utilized reflexive teaching by changing course direction and schedules to accommodate graduate student learning. The intentional effort by the professors to honor the graduate students' experiences as educators and students helped support communities of learners that encouraged, stimulated, and learned from one another, providing depth and diversity to the learning experience.

Second, the professors made curricular decisions to disrupt dominant narratives about mathematics and society. Both professors aimed to engage students in using a critical lens when completing readings and course assignments, stating that they "wanted to disrupt the notion of math and science as being white subjects" when reflecting on the thought that went into developing the course. Throughout the history course, students uncovered many facets of mathematics development previously unknown to them which disrupted the current narrative that mathematics is an isolated white male endeavor. The social justice course provided space for the graduate students to explore areas that negatively impact society, including ways to uncover systemic and humanitarian issues inside the classroom and empower students. The issues explored provided evidence of the shortfalls of education and the political nature of mathematics and contributed to the disruption of the current narrative around mathematics education.

Lastly, course assignments and readings were intended to allow the graduate students to explore "how they could take that history and use it to change their pedagogy and change their curriculum in their teaching practice, and why it would make a positive impact to do so" through social justice, empathy, action, historical understanding, and cultural responsiveness. The readings encompassed global, national, and regional mathematics history and social justice, which facilitated emotional and critical responses to the content. Student participants responded by developing culturally responsive lessons which were shared throughout the teaching community. Thus, these courses not only expanded the pedagogical practices of the graduate students but also spread into community spaces and area schools with the hope of inspiring change action in other educators.

Interviews with the student participants revealed meaningful experiences in each course led to changes in beliefs. Meaningful experiences in the courses shifted beliefs which then prompted a shift in teaching practices for the participants. Several experiences prompted changes in beliefs, including course readings, hands-on activities that put the teacher into the role of the learner, and professors modeling teaching practices. Each student participant cited readings that influenced their beliefs; these prompted a change in teaching practices for each participant. Reflecting holistically on why the readings were meaningful, participants noted that the readings caused them to question their journeys with social justice, making them more willing to engage in conversations with students about those topics. As one student shared, "It really made me examine my own self and my own biases, and the things that I do and execute in the classroom, and in my own life."

Participants shared the hands-on activities that put them into the role of the learner were meaningful and allowed them to experience different ways to learn mathematics by using history and social justice. These led to changes in their beliefs about the nature of mathematics as a human activity. One student reflected that the importance was "not only in just knowing more about the history of math but understanding how important that math is to knowing math, to understanding it as a human endeavor." Thinking of mathematics in this way helped the participants see new ways that students can engage with and understand mathematics. These changes in beliefs then inspired changes in the participants' teaching practices. Finally, student participants cited the way professors modeled teaching practices stating, "the whole class was application and exploration." In both courses, the professors used reciprocal teaching practices and allowed students the opportunity to explore their interests. The participants both described this experience as a reason for a change in their teaching practices where they now allow for student choice and direction in learning.

Though both participants were graduate students engaged in research, neither expressed how the experiences changed their views or practices in research on their own. However, once asked to reflect on how their research had been impacted, both participants stated that the courses led to a complete shift in research interests. One participant stated, "It's changed everything." Ultimately, none of the individual experiences individually sparked a change in research interest. Instead, the sum of the experiences from both courses changed the participants' views of themselves as researchers. Further, the student participants were clear that one course was insufficient to influence their positionality as researchers. Indeed, they expressed a desire for more such coursework.

The experiences of the graduate students aligned with the intentions of the professors in several ways. The professors in this study stated that student choice was essential in planning their courses. Graduate students said that they appreciated the opportunity to explore topics that were important to them and their classrooms, stating, "the activity opened my eyes to new ways that kids could understand too, through math, what other people are going through." They also appreciated the opportunities to learn from classmates' projects. This autonomy allowed for a deeper understanding of subject matter and the opportunity to serve as the teacher amongst their peers.

Additionally, both courses served the intended purpose of exposing narratives that the student participants had not previously encountered, including issues of white privilege, mass incarceration, mathematics as a collaborative human endeavor, and the contributions of marginalized people to mathematics. This exposure and consequent disruption of the dominant narrative caused both student participants to question why they had not previously been exposed to these narratives and consider how they could incorporate these narratives in their classrooms.

Implications

It is common in mathematics education to place pre-service teachers in the position of the learner, so they can develop a deeper understanding of the teaching practices being modeled. Similarly, it seems that the most meaningful activities in these courses were those that asked future mathematics educators to position themselves as classroom teachers and apply concepts of culturally sustaining and social justice mathematics teaching to their practice. Only after doing so did the student participants in the study report a shift in their epistemological beliefs, research practices, or research interests. Interestingly, both expressed that both courses were needed to shift their perspective and expressed the desire for more such coursework. This further supports the findings that a single course focused on issues of diversity is insufficient.

Both courses discussed in this study provided opportunities for the graduate students to self-reflect, learn new ways of teaching mathematics from a historical and social justice perspective, and examine culturally sustaining practices. Both courses collectively changed the graduate students' focus through culturally sustaining pedagogical practices that focused on mathematics as a human endeavor. The focus of these courses created educators and researchers who now view mathematics as rooted in an all-inclusive global history and intend to pursue mathematics curriculum and research which educates students and fellow educators in the same way.

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PRESERVICE TEACHERS' PERCEPTIONS of INTEGRATED STEM THROUGH LEARNING EXPERIENCES

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Abstract

Elementary teachers are some of the first influences that foster children's excitement and interest in STEM. Preservice teachers' perceptions influence their willingness and ability to teach integrated STEM and are therefore important to study. This study examined the perceptions of integrated STEM of seventeen elementary preservice teachers who participated in a virtual integrated STEM learning experience. Findings demonstrate the importance of using informal STEM learning experiences with elementary preservice teachers to influence their perceptions of integrated STEM. Findings also demonstrated that when elementary preservice teachers taught lessons, they planned they gained more confidence teaching integrated STEM.

Keywords: informal STEM learning, preservice teachers, perceptions

Introduction

Science, Technology, Engineering, and Mathematics (STEM) education provides authentic, real-world engagement, communication opportunities, and problem-solving with mathematics content (Acara et al., 2018; Tran, 2018). Researchers have suggested that integrated STEM pedagogies are currently missing in elementary methods classes to ensure that future teachers because (Corp, Fields, & Naizer, 2020). Research has shown a connection between perceptions and mathematical teaching practices implemented in the classroom (Philipp, 2007). The relationship between teachers' perceptions and practices is also true in STEM education (Maiorca & Benken, 2019). Often preservice teachers' (PSTs') personal experiences in mathematics remain the default mode of instruction (Foss & Kleinsasser, 1996; Thomas & Pederson, 2003). Preservice teachers benefit when they experience integrated STEM education in a face-to-face setting (Burton, 2019; Burton et al., 2020). There is limited research on how virtual informal STEM experiences influence preservice teachers' perceptions of teaching integrated STEM content.

Objectives of the Study

The purpose of the study was to examine how a virtual informal STEM learning environment influences PSTs' perceptions of integrated STEM. For this study, perceptions are defined as the attitudes, beliefs, and values PSTs hold to be true about integrated STEM (Maiorca & Roberts, 2020). The research question that guided this study was, how does a virtual informal STEM learning experience affect preservice teachers' perceptions of integrated STEM education?

Theoretical Framework

Integrated STEM has often been introduced to PSTs through informal learning experiences (Dani, Hartman, & Helfrich, 2017; Stein & Muzzin, 2018). In informal learning experiences, PSTs can engage in integrated STEM pedagogies in a low-risk environment. Jackson and colleagues (2018) also explored using non-traditional field placements to shape PSTs' perceptions while developing their pedagogical abilities in mathematics education. These informal experiences create a situation where PSTs learn through the experiences and thus change their perceptions about content.

For this study, situated learning theory (Lave and Wenger, 1991) was used to examine PSTs' perceptions of integrated STEM. The PSTs' perceptions are transformed as they learn, see, and do within the STEM teaching experience. Situated learning theory is commonly used to examine various aspects of thinking and learning related to STEM education and educational experiences (Kelley & Knowles, 2016; Roberts et al., 2018). This theoretical lens allows the experiences of PSTs to be explored in the context of the authentic activities where they experience STEM learning. Central to this situated perspective is how interactions between the learner and the environment (Lave,1988) create opportunities for learners to acquire knowledge.

Methodology

Participants included 17 female elementary preservice teachers from two large universities in the summer of 2020 and are part of a more extensive ongoing study that examine STEM education. Thirteen of the PSTs were White, three were Hispanic, and one Pacific Islander. Ten of the PSTs were taking their first methods course, four were in the middle of their methods courses, and three were taking their last methods course.

The virtual STEM learning experience was six weeks long. Elementary students meet three days a week for 2.5 hours. They participated in hands-on activities two days a week and engaged with different STEM professionals for one hour each Friday. PSTs completed observed one to two sessions of hands-on activities and then taught in pairs six to eight elementary students.

The researchers were the PSTs' professors for their elementary mathematics and science methods courses. Reflections were completed as part of the methods courses and completed by all students. To avoid the potential for coercion PSTs were recruited by a third party and the researchers didn't know which students were participating in the research study until after the grades were submitted for the courses.

Data were collected from multiple sources and included a quantitative survey, an open-ended survey, lesson plans, and reflections. We used an inductive approach to analyze data using systematic methods of data management through reduction, organization, and connection (LeCompte, 2000). The authors used the PSTs' open-ended survey responses to explore how their perceptions changed. The survey asked about their experiences, their confidence levels, how they would describe STEM, about impactful experiences, and about subjects they look forward to teaching. Open coding was initially used to create a code list by employing primarily descriptive coding to capture the big ideas in a word or short phrase (Saldaña, 2016). The first cycle coding presented an overall picture of PSTs' perceptions toward using STEM to teach mathematics. The author team consistently addressed discrepancies and reached an agreement on the codes. Inter and Intra rater reliability were above 90%, which exceeded the minimum needed for reliability analyses (James et al., 1993). After initial coding, second cycle coding was completed using pattern coding in which the authors grouped and labeled similarly coded data to attribute meaning (Saldaña, 2016). The themes that emerged are discussed in the results section.

Results and Discussion

For this study, open-ended surveys that PSTs completed were analyzed. The following themes were revealed: *ways to teach integrated STEM*, *use of inquiry and open-ended questions*, *confidence*, and *virtual environment*. The survey data revealed a bit about PSTs' perceptions, experiences, and confidence levels regarding teaching STEM and teaching in virtual environments.

Ways to teach integrated STEM

All participants were new to integrated STEM education, so perceptions before the experience were filled with questions and doubt. When asked, none had experienced integrated STEM education as a teacher or learner before this experience. The exposure to STEM teaching pedagogies and this experience impacted their perspectives on STEM, but also the subjects integrated within STEM education. Abbie (pseudonym) thought, "STEM camp changed [her] thinking on teaching math by introducing many more real-life experiences into my lesson planning." She observed a mathematics task that focused on "measurements and made scale city models to distribute food effectively." During COVID, Abbie thought this task was engaging for students because food distribution was a problem due to the large number of people dependent on food banks.

Dominique stated, "I loved every moment of learning and planning [the] STEM lesson. Going through school, I never felt that lessons were applicable and useful for later on in life." However, Dominique felt that the lessons were engaging for the students because the "students will be able to apply these lessons to their own lives and interests." She saw the benefits of using STEM because it would enable students "to make connections around them (using conceptual thinking, asking and answering inquiry-based questions, useful discourse, etc.)."

Mia noted:

Before the STEM camp, I had little idea of how STEM instruction was supposed to go. In my class that I work in, it is very much worksheets and explanations. Now having [been a] part of the STEM camp, I can tell when learning and teaching are interactive and student based.

She also noticed how the instructors used open-ended questions when she said, "I did appreciate how students were given open-ended questions." She realized the benefit of allowing students to revise their thinking.

Eighty-eight percent of the students (15/17) specifically noticed the use of inquiry and open-ended questions in the lessons. Abbie realized "that the parts where the students learn and grow the most are when they are actively engaged and asking questions on their own within the parameters of the task." Cassie realized how different teaching was from tutoring. She stated, "I tutor a lot, and I always plan lessons and activities, but I have never planned specific, open-ended questions that probe my students' thinking." Being able to plan her questions before interacting with the students made her feel more confident and allowed her "to keep [her] focus on how [she] wanted to direct [her] students thinking and inquiries."

Confidence and Enjoyment

Gabriella, who was pursuing her special education credential, said, "Before this class, I had never even looked at a science standard as well as it was never required of me." She went on to say, "After experiencing this class and the activities, I've come to understand that STEM can cater to so many unique abilities and ways of thinking." Gabriella was able to connect the skills taught in the STEM lessons to the whole child. Gabriella further explained, "STEM will also help [me] teach students lessons that are not STEM-based, such as coping skills (keeping trying to solve the problem and deal with frustration), socio-emotional skills (collaborating and teaching each other), and work ethic (being responsible and supportive)."

Simone commented that she rarely got to engage in hands-on activities as a student when she noted, "I do enjoy teaching lessons that include STEM disciplines because they are hands-on and I hardly ever got to experience that in my past educational experience, which I believe would have helped me be a better student." She further commented that she enjoyed seeing the students collaborate. Her favorite part was "watching students have little 'A-HA!' moments when they make a connection from what they are learning in class." Simone also wrote, "I think the more subjects that can be reasonably fit together in one lesson can better help students because there will ultimately be a subject or a part of the lesson that will interest and excite them." Not only did Simone see how excited the students were when they engaged in STEM but saw how integrated STEM would benefit herself and others as a learner. Stacey was also able to see how integrated STEM connected to the different content areas and created opportunities for students to be exposed to the world of engineering. This experience made Stacey feel more confident teaching because "[she] was prepared for teaching by the fact that I had to create questions and respond to student discussion on demand as in a regular classroom."

While most students reported being more confident after participating in the summer informal learning experience, some didn't feel more confident. Natalie noted she did not feel more confident because "I've never actually come up with a STEM lesson that someone else used in a classroom. I have created an integrated STEM lesson but don't know if it would be successful." This reflects the fact that their self-created lessons were not implemented in the STEM experience due to time, but instead, the lessons taught were planned by the university faculty. For Natalie, this sentiment is shared across other areas of teaching. She also stated, "similar to any other component of teaching, I can put something down on paper, and it looks good, but it might not resonate the same way in the classroom." Another participant stated, "I am not very confident in my ability to generate integrated STEM lessons. I need more teaching experience to make me confident."

The feedback showed an increase in both confidence and enjoyment, but there was still hesitation and, as Natalie stated, a need for more experience. It suggests that PSTs need to not only have experiences learning about integrated STEM, teaching lessons, and planning lessons but also that they need opportunities to teach the lessons they plan.

Virtual Environment

Due to COVID, the informal STEM learning experience was shifted rapidly to a virtual experience. The informal STEM learning experience was the first experience with students in a virtual setting for all the preservice teachers. Amelia was "really nervous because I did not know how engaged the students would be, or if they just wouldn't want to do the activities." However, Amelia stated after the experience,

[she] was proven wrong and learned that they loved it. It was really impactful to see them be so excited to talk about STEM or show me what they created during camp. It made me realize that teaching can be done virtually, even if it is difficult.

For Amelia, the experience challenged her initial beliefs about online learning. The informal STEM learning experience also helped Mia realize "learning doesn't have to stop just because we aren't in a physical classroom or camp." The informal STEM learning experience made Amelia and Mia realized that engaging students in a virtual setting is possible.

Not all the students thought the experience was a positive one. Jordan stated, "While I did love getting to see the lessons over the internet, being there to see the students participate in person would be so beneficial." Jordan also stated, "[Teaching virtually] is very different from teaching in-person, and I was able to observe how the teachers' answered questions and [responded] to students." Although Jordan did not prefer teaching online, she felt the virtual STEM learning experience helped her prepare for virtual learning because it demonstrated "how teachers can react and solve a problem online, and the necessary materials and support a teacher would need to teach through Zoom." The experience of teaching and observing virtual learning experiences helped PSTs consider ways that online learning can differ from in-person teaching and yet still be engaging.

Implications

This study demonstrates the importance of providing elementary preservice teachers the opportunity to engage virtual informal STEM learning experiences with students to positively influence their perceptions of integrated STEM. The informal STEM learning experience in this study allowed preservice teachers to interact with students in an authentic setting and enabled the preservice teachers to see how students could engage in inquiry-based problem-solving in a virtual setting. This study also demonstrates the need for PSTs to have the opportunities to plan and teach their own integrated STEM lessons. Additional studies in which PSTs plan and implement their own lessons in STEM environments could be informative to see how perceptions changed from this additional opportunity. Future research could focus on following preservice teachers who participated in informal STEM learning experiences in their classrooms to determine if the positive shift reported correlates to effective STEM teaching practices.

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TEACHER NOTICING WITH 360 VIDEO

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Abstract

Teacher noticing is a crucial facet of math and science teacher education, with one goal being to shift preservice teachers' (PSTs) noticing from teacher-centered to student-centered. In this study, we used 360 videos to examine PSTs' choices of where to look in a classroom. We discuss differences in attending behavior of those PSTs who focused on the specific themes of teachers' scaffolding and student engagement.

Keywords: Teacher noticing, 360 Video, Teacher education

Introduction

One valuable aspect of teacher education is developing professional teacher noticing abilities for the classroom. Professional teacher noticing includes the ability to notice what is important in the classroom environment and then connect that to broader education principles or practice (van Es & Sherin, 2002). Noticing is an active engagement where teachers choose to direct their attention to classroom activities and circumstances (Erickson, 2011). In particular, noticing students' ideas is a critical component of teaching and should be developed early in teacher education programs (Stockero et al., 2017). However, there is often concern that novice teachers focus too much attention on teachers (self or others) instead of on students' engagement (Mitchell & Marin, 2015).

In this study of preservice teachers, we use 360 videos to analyze their professional teacher noticing abilities of a mathematics lesson. The major finding in this study is the relationship between attending to teacher scaffolding and student engagement.

Objectives of the Study

The purpose of this paper is to examine the relationship between where PSTs chose to attend in a 360 video and the specificity of their descriptions surrounding themes of teacher scaffolding and student engagement. We utilized 360 videos to explore PST noticing of a mathematics lesson. 360 videos give the PST an immersive experience in a math classroom, thereby allowing them to potentially develop their noticing skills. Another objective of this study was to ascertain what PSTs attended to in their writing and how it relates to what they viewed during the 360 video experience. For clarification purposes, we refer to participants' written noticings as attending, and for participants' physically viewing something, we use the term focusing. Giving PSTs the opportunity to observe and reflect on mathematics lessons lends exposure and experience in classroom environments.

Related Literature

Teacher noticing has emerged as a valuable construct in math and science education. It is a form of situational awareness that involves the teacher recognizing key aspects in the classroom while using reasoning to process the information (Stockero et al., 2017). This ability to notice and interpret events within a classroom is referred to as a teacher's professional vision (Sherin, 2009). Teacher noticing is relevant in teacher training as PSTs initially focus on the teacher's action or other behaviors not related to the content (Barnhart & van Es, 2015; Huang & Li, 2012, Kosko et al., 2020), whereas experienced teachers process how students specifically engage in content (Jacobs et al., 2010). In their study on preservice teachers noticing Amador & Weiland (2015) found that preservice teachers tended to focus on classroom environment and teacher pedagogy.

Preservice teachers often develop their professional noticing within field experience when they are placed in an actual classroom. This development of professional noticing can happen within the classroom but also can be developed with the use of certain technologies such as video (van Es & Sherin, 2002) and precisely that of 360 videos (Ferdig & Kosko, 2020). 360 videos give the viewer the opportunity to look omnidirectionally, thereby allowing the viewer to choose where they attend. Additionally, it provides a sense of standing and being present in the classroom (Ferdig & Kosko, 2020; Walshe & Driver, 2019). This sense of being present in the classroom during a 360 video is embodiment.

Embodied cognition is the potential for cognition through our experiences with sensorimotor capacities embedded in biological, psychological, and cultural contexts (Varela et al., 2016). Cognition and sensorimotor connections are evident in learning and can be utilized in the field of education research (Alibali & Nathan, 2012). Embodied cognition has been used as a theoretical lens for explaining teachers' professional noticing (Kosko et al., 2020; Scheiner, 2021). It stands to reason that professional noticing would be connected with embodied learning or cognition as it recognizes the link between teachers attending physically and mentally to what is happening in the classroom.

Methodology

Sample and Procedures

This study included 21 participants enrolled in an undergraduate education technology course. Participants were PSTs registered in a Midwestern University based in the United States. Demographically they were predominantly female (76.2%) and white (95.2%), majoring predominately in secondary education (42.9%), early childhood education (19.0%), and middle childhood education (9.5%). Regarding technology, the majority of participants considered themselves to be more technologically savvy than not (81.0%), and the majority had prior experience with 360 videos (71.4%).

During the Spring 2020 semester, as a stay-at-home order was in place due to the COVID pandemic, participants were engaged in this online study. As part of the study, participants initially viewed a tutorial video of how to watch a 360 video. Next, they watched a 360 video of a grade 4 (ages 9-10) elementary classroom. The video was 5 minutes, 49 seconds and recorded students working in small groups to find equivalent fractions. In the video, elementary students worked with fraction strips and determined the common denominator through arithmetic. After viewing, PSTs described what they noticed about students' mathematical thinking and then viewed the video a second time but were asked to focus on one moment involving students' mathematics that they considered pivotal. PSTs screen recorded their viewing sessions, providing additional data for analysis. Table 1 includes a classroom map displaying camera and student locations.

Analysis

We used a convergent mixed methods design to examine the relationship between where PSTs chose to attend in a 360 video and the specificity of their descriptions of the classroom scenario. Convergent mixed methods design allows scholars to use qualitative and quantitative methods to converge data and better understand a given phenomenon. In this paper, we qualitatively examined PSTs' written noticing using Systemic Functional Linguistics (SFL). SFL examines how grammar functions to convey meaning (Eggins, 2004). In this study, we focused on how PSTs used reference and reference chains to convey information about what they noticed. Concurrent with this analysis, PSTs recorded first viewing of the 360 videos were quantitatively coded for the particular region of the classroom they focused on at any given second (see classroom map in Table 1). We then quantified the presence of qualitatively observed themes and examined PSTs' distribution of focus and with the presence of specific themes. To further understand trends in statistical analysis, we then examined key moments in PSTs' screen recordings to triangulate findings and results (Creswell & Plano Clark, 2011).

Results and Discussion

Qualitative Findings

Analysis of PSTs' reference chains yielded several emergent themes, including teacher scaffolding, students' engagement, hands-on work, mathematics content, and group work. In this paper, we focus on PSTs' reference chains attending to students' engagement and teacher scaffolding. Reference chains representing the student engagement theme referenced students and used the system of transitivity (i.e., verbs) to convey material and mental processes as ways of engaging in the class and content. For example, Natasha's excerpt (Figure 1) references "students tried dividing…realized [they] couldn't…" to point to ways that students were engaging in class.

Student Engagement	**Teacher Scaffolding**
When some students tried dividing fractions, // **they [students] realized that the *couldn't*** **divide 5 by another number because 5 is prime.** **Also, for [students] finding an equivalent fraction for 3/8, //** **students realized they *could* not use fraction strips //** **because they didn't have strips//** **that *could* show 6/16 or higher denominators.**	The teacher **encouraged** a student to keep the written work he had done// *even though* he **could not show i**t with his number strips. She [teacher] then// asked him[student] to add on another answer // that was workable with his strips. Another time in the video she [teacher] had to remind the same student that he needed to also **work it out** with his strips. This extra attention and encouragement [from teacher] given to students who need it, for whatever reason, **helps** them[students] immensely, There are teachers that **would have told** him he was wrong// simply because it [student's work] **did not match up** with the visual aspect of the assignment// and this would have left the student **feeling defeated**. Instead, she[teacher] **praised** him [student] and **encouraged** him[student] to also work towards the task at hand.

Figure 1. Examples of emergent themes for Natasha (left) and Carol (right).

Teacher scaffolding emerged via reference to the teacher acting upon students. This was evident in Carol's reference (Figure 1) that "the teacher encouraged a student… asked [student] to add on…*had to* remind the same student…" and so forth. Transitivity here serves to convey ways that the teacher acts upon student(s) in various ways that coincide with forms of scaffolding. We distinguished this form of reference to the teacher from others where the teacher may be referenced as writing on the board or posing a problem (as those do not connect to their acting upon students). Once these themes emerged from the analysis, participants' written noticings were coded for the presence or absence of these themes. We used Cohen's Kappa to examine for inter-rater reliability and found sufficient agreement for student engagement (K = 0.548) and teacher scaffolding (K = 0.777). Twelve participants attended to teacher scaffolding, 16 attended to student engagement, with seven participants attending to both.

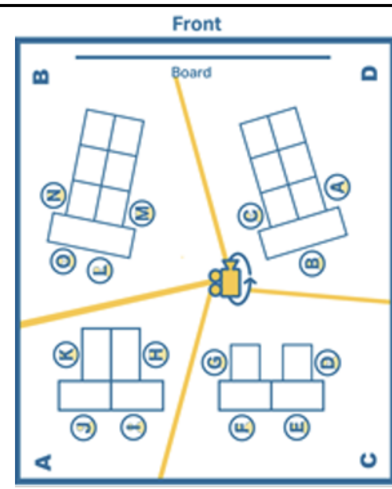
Quantitative Results

A Chi-square statistic was calculated to examine the relationship between PSTs' written noticing and their focus in the 360 videos. The resulting statistic is not independent of chance ($\chi^2(df{=}8) = 191.797$, $p < .001$), suggesting that PSTs' attending to one or both themes corresponded with differences in where they focused in the 360 videos (see Table 1). Specifically, PSTs who attended to teacher scaffolding (or both teacher scaffolding & student engagement) focused on Section B of the classroom (the teacher's location) for a longer time than their peers.

Table 1.

Distribution of Focus and PSTs' Attended Themes.

	Sections of the Classroom Map					Total
	A	B	C	D	n/a	
SE	156 *228.43*	905 *958.28*	348 *394.25*	1669 *1483.38*	23 *36.66*	3101
TS	57 *132.74*	596 *556.89*	274 *229.10*	848 *862.00*	27 *21.30*	3101
Both	249 *176.57*	794 *740.72*	351 *304.75*	961 *1146.62*	42 *25.34*	2397
Total	405	1699	699	2630	65	5498



Note: Student Engagement (SE) & Teacher Scaffolding (TE) are abbreviated. Observed counts are regular text & expected counts are italicized. Indeterminant focus is indicated by 'n/a'.

PSTs who attended to student engagement focused proportionally longer on Section D than their peers. Notably, this section included a group of students who interacted significantly throughout the lesson, and the camera was near to their table (camera was also adjacent to the table in Section C). Another result of note is the proportion of seconds classified as 'indeterminate' (labeled n/a in the table). These were moments where PSTs did not appear to have a section of focus (focusing on the ceiling/floor). Notably, PSTs attending to both student engagement and teacher scaffolding had a much larger number of observed indeterminate seconds of focus than was expected by chance ($z = 3.44$, $p < .001$).

Merged Analysis

To better understand the statistical analysis and corresponding qualitative findings, we examined tendencies in participants' viewings. Specifically, we created graphics illustrating where each individual participant focused at any given time. We then grouped participants by whether they attended to student engagement, teacher scaffolding, both or neither and compared their 'timeline graphs' for patterns that corresponded with the statistical findings (see Table 1). For example, we looked for whether there was a time period that PSTs attending to teacher scaffolding tended to focus on Section B in the video, and we did the same for PSTs attending to student engagement for Section D. Three example timelines are illustrated in Figure 2, which we use to discuss general trends observed. PST's who attended only to student engagement focused on section D more than expected by chance, whereas their peers did so proportionally less. Notably, between 3:12 to 5:12, all participants showed a substantial increase in focusing on section D, when students were engaged in working together to solve the math task at hand. However, PSTs attending to teacher scaffolding often shifted their focus to other areas of the classroom and back while those attending to student engagement illustrated sustained focus (see Figure 2). PSTs attending solely to teacher scaffolding focused on section B more so than expected (see Table 1 & Figure 2). This was particularly evident during periods of whole class discussion such as between 5:04 to 5:32 when the teacher is attempting to finalize students' review of using the common denominator or fraction strips to compare fractions. Although most participants did focus on the teacher during this timeframe (see Natasha in Figure 2), PSTs such as Carol, who attended to teacher scaffolding, had a more sustained focus on the teacher.

Those PSTs who attended to both student engagement and teacher scaffolding were observed to have significant movement from one section of the classroom to the next. The aggregated number of seconds illustrated in Table 1 suggests a more sustained focus in section B, but analysis of participants' timelines and screen recordings suggests this was more often a touchstone of sorts. For example, Sylvie's timeline in Figure 2 visually conveys a significant shift in focus over the course of her viewing. Every so often, she would stop for brief periods at either section D or B. For most participants attending to both themes, the common 'stopping point' was section B, with Sylvie serving as a unique variant in this set of participants.

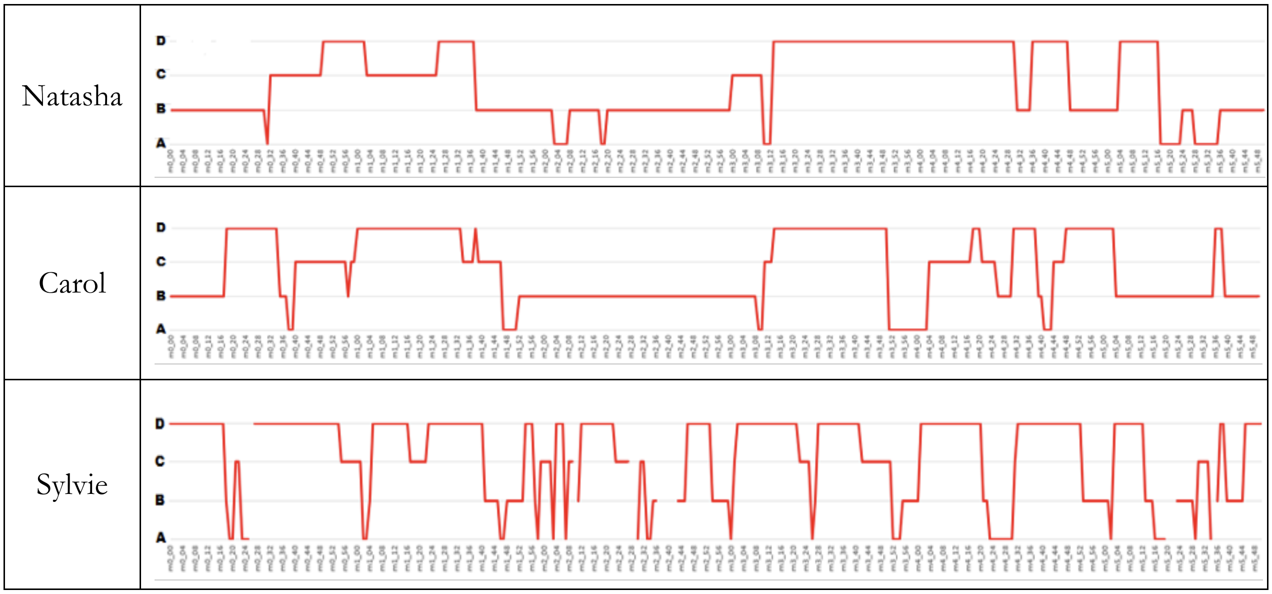


Figure 2. PSTs' Sections of Focus by Time in the 360 Video.

Discussion

The significance of these findings reinforces the idea that PSTs' noticing is an embodied experience as their physical focus during a 360 video experience was connected to their written noticings. These findings can help teacher educators shift PST noticing from teacher-centered to student-centered thereby helping PSTs on their journey of becoming professionals.

Implications

This study allowed us to have an in-depth view into PSTs viewing and noticing during a 360 video experience. In this study, we looked at how 360 videos elucidate PSTs' noticing in connection with their physical movements and written responses of the virtual classroom. This research has value in contributing to a better understanding of PST professional noticing within math and science education.

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Acknowledgements

Research reported here received support from the National Science Foundation (NSF) through DRK-12 Grant #1908159. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of NSF.

DEVELOPING A MATH-SCIENCE PARTNERSHIP TOWARDS SUPPORTING ELEMENTARY STUDENTS' MATH IDENTITIES

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Abstract

Students' math identities form the lens by which they perceive and interact with math, making it essential that they see math as a robust problem-solving process and as a viable career path. This paper describes an exploratory research project aimed at engaging elementary students in rich, open-ended, integrated math and science learning opportunities to create positive math identities. Findings reveal students' developing more positive math identities by redefining characteristics of math success and by making connections between math, science, literacy, and art. Multidisciplinary learning opportunities shaped how students engaged with mathematics in the classroom.

Keywords: Mathematics Identity, Multidisciplinary Learning, STEM

Introduction

Next Generation Learning Standards for Mathematics highlight the changing expectations for mathematics achievement, including 21st century mathematical skills of reasoning, collaboration, and flexibility. As such, students need to explore complex concepts from different angles and perspectives, engage and in collaborative discourse, and see math as a worthwhile endeavor. National science standards also focus on science as a human endeavor, promoting creativity, persistence, and reasoning and encouraging students to see that any individual can practice science. The goal of our research is to use a multidisciplinary approach to increase student interest and engagement in science, technology, engineering, and math (STEM) as a set of disciplines and possible career paths.

Identity is a useful construct for exploring students' beliefs and perceptions of mathematics as well as why students disengage from mathematics. Developing positive math identities is critical for students to become successful math learners and to pursue careers in STEM-related fields (Cribbs et al., 2021). Students' math identities and their mindsets about math form the lens by which they perceive and interact with math necessitating that they forge meaningful connections with math as a robust problem-solving process and as a viable career path. Our research explores changes to elementary students' math identities using an integrated, multidisciplinary teaching approach to provide unique insights into how students view themselves as both math learners and future STEM practitioners.

Objectives of the Study

Engaging elementary students in rich, open-ended, integrated STEM learning opportunities can support the development of positive math identities. We define 'integrated STEM' as a multidisciplinary instructional approach that engages students collaboratively by providing solutions to real-world problems (Bryan & Guzey, 2020). This exploratory research project includes learning opportunities devoted to engaging students with: (i) careers in STEM, (ii) literature connections, (iii) real-world tasks, and (iv) challenging math problems. We aim to address a need to develop and incorporate an elementary curriculum that is open-ended, multidisciplinary, and supports positive math identity formation. We partnered with two fourth-grade teachers to develop and implement integrated STEM lessons to engage students with math from multiple perspectives: as students, citizens, and future STEM practitioners. We profile one teacher here, Ms. Russo, to highlight her inclusive classroom context and STEM teaching approaches. We identify changes in students' math identities using a pre-and post-math identity survey. The research question guiding this study is: How can engaging students in rich, open-ended, multidisciplinary learning opportunities support the development of positive math identities?

Related Literature

Mathematical identity can be defined as "the dispositions and deeply held beliefs that students develop about their ability to participate and perform effectively in mathematical contexts and to use mathematics in powerful ways across the contexts of their lives. (Aguirre et al., 2013, p. 14). In this way, mathematics identity is not only a set of defining individual beliefs but also a method to make changes to current and future experiences. Students' math identities are "a critical component of framing the knowledge, skills, habits, attitudes, beliefs, and relationships that students need to develop as successful mathematics learners" (Allen & Schnell, 2016, p. 400). We utilize the definition and facets of mathematics identity as a conceptual framework to guide our work. Because identities are dynamic and malleable, identity formation is impacted by learning experiences in school and relationships with peers, teachers, and caregivers. Students need rich, open-ended learning opportunities to make sense of math and to see themselves as not only math learners but math-doers. Successful math learners "approach math with a mathematical mindset, knowing that math is a subject of growth and that their role is to learn and think about new ideas" (Boaler, 2019, p. 29). If students only see math as a set of rote rules and procedures to be learned and followed without meaning, they will likely form fixed mindsets and see themselves as "bad" at math (Dweck, 2006), which can influence the perception of mathematics, achievement, and future career goals (Boaler & Greeno, 2000).

A multidisciplinary approach to STEM education can benefit students who struggle in mathematics (Hwang & Taylor, 2016). This approach incorporates different academic disciplines, contexts, and perspectives to examine a topic, theme, or question and can be used to deepen and enhance student learning (Jehlička & Rejsek, 2018). While research supports the use of a multidisciplinary approach in elementary education, additional work is needed to support and understand students' development of positive identities while engaging in integrated learning activities.

Methods

Context of the Study

The context of this study is a university-school partnership between the State University of New York at Cortland and two elementary schools located in the Northeastern US. The aims of this partnership are to create positive student math identities by developing and implementing lessons and activities that enable elementary students to engage with math from multiple perspectives. To do so, university STEM education faculty worked closely with partner teachers to develop and implement a series of six integrated, math-centered STEM modules during the spring 2021 academic semester. This study profiles the development and implementation of these modules by one partnership teacher.

Participants

The participants are a Grade 4 elementary school partner teacher and her students. Ms. Russo is a special education teacher at a highly diverse and urban elementary charter school in her first year of teaching who had six students enrolled in her class at the time of this study. Her students had differing social and cognitive abilities, including math and reading abilities ranging from Grades 2 to 5 according to standardized test results. To note, Ms. Russo was familiar with using integrated STEM teaching approaches to teach math and emphasized differentiation within each of her lessons to reach all students. The term "urban" corresponded with the school's proximity to the city center and a diverse student population. Pseudonyms were used to protect the anonymity of the participants.

Module Design and Implementation

The series of math-centered STEM modules for this study were designed to support the formation of elementary students' math identities and promote growth mindsets (Cribbs et al., 2021; Dweck, 2006). Each module included a: (i) discrete, standards-based STEM topic or theme (e.g., taking measurements), (ii) connection to literacy (e.g., a read-aloud portion), (iii) discussion and STEM journal prompts, (iv) open-ended, cognitively demanding math problem, and (v) STEM career connection. Tasks that involve a high level of cognitive demand (level of thinking required) allow students to develop mathematical proficiency and make use of prior knowledge and multiple resources to solve. For example, one module focused on engaging students with using math operations to design a tower made of blocks that met distinct criteria and constraints (i.e., Performance Expectation 3-5-ETS1-1; NGSS Lead States, 2013). This lesson included a read-aloud of Ashley Spire's *The Most Magnificent Thing* as a literacy connection, a journal prompt, and discussion about struggling and persisting in math (e.g., "how do your struggles help you learn and grow?"), and students were introduced to the STEM career of engineering. Other module themes included visualizing math, taking measurements, and critical thinking and problem-solving. Ms. Russo implemented these modules on a weekly basis. Ms. Russo supported module implementation by allowing students to engage in rich discussions, collaborate on activities, and by helping students make connections to their own ideas and lived experiences.

Data Collection and Analysis

This exploratory research used case study and survey methods to identify potential changes in students' math identities following engagement with integrated, math-based STEM lessons. Ms. Russo was chosen as a case of significance because of her inclusive classroom context and distinct drive to utilize STEM approaches to teach math. Data were collected via pre-and post- student math identity surveys (n = 5 pre-, 5 post; 10 total), teacher lesson reflections (n = 5), and teacher-researcher debriefs (n = 6). Student surveys were deployed immediately before and after the implementation of the modules. This researcher-developed survey was comprised of 25 agree/disagree statements and open-ended questions aimed at uncovering students' math identities that included components addressing: (i) math beliefs, (ii) math dispositions or attitudes, and (iii) engagement in math problems (Appendix A). Reflections represented Ms. Russo's personal lesson observations and were completed following the implementation of each module. Reflections included her successes and challenges, as well as notable student engagement and quotes. Ms. Russo also debriefed orally with the researchers following each lesson. These open-ended 30–60-minute conversations focused on asking Ms. Russo about student responses, student work, and teacher observations; sessions were later transcribed by researchers.

Surveys were analyzed for changes in students' responses with a focus on students' recognition, formation, and solidification of math identities (n = 4 students; 8 surveys total). Data were analyzed using open coding with a focus on students' math identities. Researchers analyzed data independently and met regularly to discuss and identify emerging themes (Creswell & Creswell, 2017).

Results and Discussion

Survey results were used to explore changes to student responses. Teacher anecdotal data and debrief sessions were analyzed to examine descriptions of discussions and student work related to math identity development. Results from each data source are described in the following sections.

Survey Data

The pre-and post-survey results demonstrated students' changing beliefs about the nature of math intelligence, the role of mistakes and challenges in math, and future math goals. Two agree/disagree statements addressed students' feelings and beliefs about the nature of math intelligence. In the pre-survey responses to "I cannot change my math intelligence," only half the students answered that they disagreed with this statement, but after module implementation, all students disagreed with this statement. Several statements addressed the students' feelings about making mistakes in math. The pre-survey results indicated that only 25% agreed that mistakes help them learn while 100% agreed with the statement in the post-survey. Two questions addressed students feeling about tackling challenging problems in math. After the module implementation, all students (100%) responded that they felt challenging problems made them want to work harder and 75% responded that they liked challenging math problems.

Some responses did not change after the module implementation. For example, in both pre- and post-surveys, 50% responded that they agreed boys are better at math than girls. Notably, the only female student changed her response from agree to disagree. Also, students maintained positive views on the importance of math in careers in both the pre-and post-surveys. One theme from the open response questions was that all the students had clearer math goals by the post-survey. One boy had the initial goal of "to be smart" but after the modules shared that his goal was "to get better at division." This also shows his shifting perspective in terms of the role of *effort over smartness* in math. Overall, both agree/disagree statements and open-ended responses showed students' building stronger math identities open to meeting their math goals through the process of making mistakes and taking on challenges.

Student Responses to Redefining Math Learning

Teacher data and debrief sessions revealed high engagement around content related to growth mindset and redefining success as a math student. Students explored evidence that every person can be a math person and possesses math abilities and strengths, that the brain is a muscle that can grow when faced with a new problem, and that mistakes and challenges help math brains grow. Ms. Russo's noted that students "seemed very shocked" when these ideas were introduced, and the class participated in a rich discussion to make sense of ideas like mistakes and struggles are key for unlocking new learning. The cognitive conflict that students experienced supports the pre-survey data that shows students' mainly fixed mindsets about what it means to be a successful math learner. Despite showing strong interest and openness to these ideas, students consistently provided examples of how these concepts seem disconnected from their lived experiences. For example, one student said, "if everyone is a math person then why does my sister get bad grades in math and then my mom gets mad at her?" One student commented that thinking slowly and deeply about math concepts makes a lot of sense, however, then why does he feel rushed when working on math in class? Another student agreed, stating her dad always tells her to "hurry up and finish" when working on math at home. These results support research that highlights society's damaging tendency to believe that math is for those who are "naturally gifted" in the subject and that math is about procedures, facts, and speed; myths that can hinder student advancement in the subject (Boaler, 2019).

During module implementation, students discussed the importance of struggling and making mistakes to make room for new learning. As a class they came up with a variety of strategies to utilize when stuck on a challenging problem, including talking to a friend, drawing a picture, asking questions, making a list, taking a break, and asking for help. Ms. Russo's reports reveal that students seemed to be making progress toward embracing themes of the modules around persistence, problem-solving, and collaboration. However, when students were faced with a challenging task, they often got frustrated and relied heavily on the strategy of "asking for help". Over time, Ms. Russo discovered that she could guide and scaffold student learning by having students communicate, collaborate, and represent their ideas in different ways. She also often utilized whole-group collaboration where the class systematically tackled a challenging problem. For example, when students were asked to find different combinations of block towers that could be made from three, four, or five colored blocks students decided to give each person a pattern to test out ("i.e. one student finds all combinations where the red block is on top) and to have the teacher help document and combine their solutions. According to Ms. Russo, as the class progressed through the lesson modules, students demonstrated greater sustained effort and new strategies for dealing with struggles, mistakes, and challenges.

Student Responses to a Multidisciplinary Approach

Ms. Russo reported strong interest and rich discussions when math content was incorporated with the reading of picture books with discussion prompts, when students explored connections between math and art, and when students learned about careers in STEM. Multidisciplinary content enabled students to see diverse individuals learning, struggling, and defining their own path as a math learner or as a STEM practitioner. For example, in *The Most Magnificent Thing*, students related to the character's struggles of making mistakes and getting frustrated while trying to construct her most magnificent thing. Students provided many examples of this happening in their own lives. Students read *Maryam's Magic,* the story of the first woman, and first Iranian, to win a Fields Medal whose creativity helped her overcome many challenges. After the story, students were asked to draw a mathematician. One student drew a teacher who had previously expressed his own struggles in math and stated, "he doesn't give up on us." Another student said, "I just drew a bunch of people because they are all mathematics, they take their time, keep going, and use any kind of tools in front of them." Another student agreed, "literally anyone can be good at math, so long as they put their mind to it." Anecdotal data demonstrated that students began to redefine characteristics of mathematical success to include overcoming challenges, collaborating, using creative tools, and representing math ideas in new ways. Integrating the teaching of math across disciplines allowed for the exploration of diverse individuals who succeeded in math and science by forging their own paths, and began to shape student beliefs as well as how students engaged with mathematics in the classroom.

Implications

The results provide important implications for university partnerships between STEM researchers and teachers and school districts. When STEM researchers and teachers join forces, they can create powerful lessons that contribute to students' development of positive math identities. These partnerships should consider, as we did, starting with math and science dispositions and practices instead of with content standards. This way, teachers promote the crucial aspects of math identities including problem-solving, creativity, collaboration, persistence, and reasoning. School districts can support teachers who work together to find creative ways to integrate math, literacy, art, science, and careers in STEM into their curriculum. These improvements in curriculum and instruction can promote productive dispositions towards math and can change students' beliefs about what it means to be successful in math. It can also impact students' ability to use mathematics in powerful ways across the contexts of their lives. While our study was limited to a small sample, we plan to continue to use our modules with larger groups of teachers and students and encourage others to continue research in this needed area.

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Appendix A

Math Identity Survey: https://tinyurl.com/7rwj4puv