School Science and Mathematics Association
Founded in 1901

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SSMA Annual Convention
Colorado Springs, CO
October 19-21, 2023

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School Science and Mathematics Association
Founded in 1901

The School Science and Mathematics Association (SSMA) is an inclusive and thriving professional community comprising educators and researchers dedicated to enhancing the fields of school science and mathematics. Since its inception in 1901, SSMA has remained a steadfast platform for prominent mathematics, science, and STEM educators to showcase their research and publish scholarly works for over 120 years.

SSMA's primary focus lies in fostering research-based innovations within K-16 teacher preparation and continuous professional development in the realms of science and mathematics. This organization caters to a diverse audience, including higher education faculty, K-16 school administrators, and K-16 classroom instructors.

SSMA's mission can be summarized by four key goals:

- Cultivating a close-knit community of educators, researchers, scientists, and mathematicians.
- Advancing knowledge through rigorous research in science and mathematics education and their effective integration.
- Informing and enriching teaching practices by disseminating scholarly works within the fields of science and mathematics.
- Influencing education policies in science and mathematics at local, state, and national levels.

The proceedings of the 122nd Annual Convention represent SSMA's rich traditions and its promising future, serving as a testament to its enduring commitment to the advancement of science and mathematics education.

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PREFACE

These proceedings are a written record of some of the research and instructional innovations presented at the 122nd Annual Meeting of the School Science and Mathematics Association held October 18-21, 2023, in Colorado Springs, CO. The blinded, peer reviewed proceedings include seven papers regarding instructional innovations and research. The acceptance rate for the proceedings was 64%. We are pleased to present these Proceedings as an important resource for the mathematics, science, and STEM education community.

Rebekah Hammack & Beth Cory
Editors

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EVALUATING THE UNIVERSAL SCREENERS FOR NUMBER SENSE: A VALIDATION STUDY

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Abstract

The Universal Screeners for Number Sense (USNS) measure the construct of number sense, which has been characterized in numerous ways over the last 50 years. A purpose of this study is to provide validity evidence regarding the USNS assessments, which may support scholarship on numeracy and practical work in K-12 schools. Findings indicate that the USNS assessments may be used confidently to measure students' growth in number sense.

Keywords: number sense, formative assessment, validity, validation

Introduction

Assessment is central to understanding what and how students learn (Black & Wiliam, 1998). Understanding students as individuals, their reasoning and problem solving skills, and knowledge that students bring to the classroom has potential to enhance students' learning outcomes (National Research Council, 2001). Put simply, teachers are better poised to support student learning when the teachers have greater knowledge of their students. Unfortunately, the information that teachers rely on to understand their students' knowledge and abilities are collected through distal standardized assessments that create vague pictures of student performance (Popham, 2001). Such assessments may not be designed to provide teachers with a detailed understanding of students' strengths and weaknesses. The inferences that teachers draw from assessment results, and how teachers subsequently use that information, reflect issues of validity (AERA et al., 2014; Folger et al., 2023). The Universal Screeners for Number Sense (USNS) are a series of K-6 open source assessments that integrate interview and written tasks. These assessments help teachers to hone in on the key skills, concepts, and developmental milestones of students. Through interview tasks and corresponding item rubrics, teachers are provided with a structure for (1) observing students as they solve problems and (2) listening to student reasoning. This format provides teachers with rich details about their students' number sense.

Purpose

The purpose of this validation study is to evaluate the Universal Screeners for Number Sense (USNS) for use in grades K-5, as a measure of students' number sense. An outcome from this study is to share evidence to support the use and interpretations of the USNS, which may interest university scholars, teacher educators, and K-12 practitioners and administrators. The following four claims inherent to the USNS are the focus of this study: (1) USNS assess K-5 students' number sense in ways that are aligned to the Common Core State Standards for Mathematics; (2) USNS are effective formative and progress-monitoring assessments; data can be used to interpret student growth between time periods; (3) USNS grade-level assessments demonstrate effective construct development to measure students' number sense; (4) USNS assessment items function reasonably well in collectively measuring a single construct (i.e., number sense).

Related Literature

Validity is an attribute of the interpretation of test scores for proposed uses of tests (AERA et al., 2014). The degree to which an interpretation and use of test scores is valid depends on the quantity and quality of supporting evidence (AERA et al., 2014). *The Standards for Educational and Psychological Testing* describe five sources of validity evidence: test content, response processes, internal structure, relations to other variables, and consequences of testing (AERA et al., 2014). Each source of evidence, briefly described in Table 1, supports differing claims inherent to the interpretation, and subsequent use, of test scores (Folger et al., 2023). For instance, evidence based on relationships to other variables may support claims that performance predicts future academic achievement. An additional example, evidence based on test content may support claims that test items align to a specific set of mathematical standards. Scholars agree that a central goal of validation is to construct and evaluate "arguments for and against the intended interpretation of test scores and their relevance to the proposed use" (AERA et al., 2014, p. 11). One framework to guide a validity argument is an interpretation and use statement, which has a focus on claims about interpretations and uses for an assessment, and supporting evidence (Carney et al., 2022).

Construct Articulation

The USNS assessments measure the construct of number sense, which has been characterized in numerous ways over the last 50 years. Sowder (1989) describes number sense as (a) being able to conceptually relate number and operation properties; (b) the ability to use number magnitude to compare numbers, recognize when calculation results are not reasonable, and to apply non-standard algorithmic strategies when performing mental calculations; and (c) being able to solve problems involving numbers using flexible and creative strategies. Kalchman and colleagues (2001) employ a similar definition: "Number sense is: (a) fluency in estimating and judging magnitude, (b) ability to recognize unreasonable results, (c) flexibility when mentally computing, [and] (d) ability to move among different representations and to use the most appropriate representation characterized" (p. 2). Berch (2005) posits, "Possessing number sense ostensibly permits one to achieve everything from understanding the meaning of numbers to developing strategies for solving complex math problems" (p. 334). Collectively, these characterizations (Berch, 2005; Kalchman et al., 2001; Sowder, 1989) present number sense as encompassing topics including but not limited to fluency, magnitude, number recognition, representation, and communication. These topics are also taken up in the National Council of Teachers of Mathematics (2000) framing of number sense.

Table 1

Description of the Five Sources of Validity Evidence (AERA et al., 2014)

urce of Validity Evidence	Description
Test Content	Test content includes the wording and format of test items or tasks. Validity evidence based on test content would indicate that test items, or test content, align to the construct a test intends to measure.
Response Processes	Response processes describe the alignment between test takers' performance or behavior and the construct a test intends to measure. In cases when a test relies on observers or judges to evaluate test takers, evidence may include "the extent to which the processes of observers or judges are consistent with the intended interpretation of scores" (AERA et al., 2014, p.15).
Internal Structure	Internal structure may indicate the degree to which test items conform to the construct a test intends to measure. Such evidence may be collected through analysis of test dimensionality and item interrelationships.
Relations to Other Variables	Relations to other variables examines the degree to which test scores are, or are not, related to some ancillary variable. The *Standards* describe several examples when relations to other variables may be of interest, such as: (a) hypothesized differences in group performance, (b) the degree to which test scores predict future performance, and (c) whether test scores from different tests measuring a similar construct produce a convergent association.
Consequences of Testing	Consequences of testing presents the intended and unintended consequences following the interpretation and use of test scores. Consequential evidence evaluates "the soundness of [test score] interpretations for their intended uses" (AERA et al., 2014, p. 19).

Operationalization and Administration

The USNS consists of interview-based and paper assessments designed to assess student's number sense. Assessments are administered three times a year: fall, midyear, and spring. The interview assessments are designed to be completed in approximately five minutes. The written portion is designed to be completed in approximately 10 minutes.

As screening assessments, the USNS are designed to help teachers identify students who might be at risk of accessing and engaging with grade-level mathematics content. However, these assessments also are intended to help teachers perceive trends in students' performance, and identify skills and topics that might need to be addressed in small groups or with their whole class.

Method

This validation study employed a multi-method research design to examine the four validity claims. Two data sources were used for this study. First, a survey was distributed to an expert panel of classroom teachers, teacher leaders, and education professionals to collect quantitative and qualitative data related to USNS. Survey data were used to evaluate claim 1 and claim 2. The expert panel consisted of 19 education professionals who have administered and scored more than 11 different USNS screeners. All expert panel members had a minimum of four years' experience as a classroom teacher, with nearly all (i.e., 98%) panel members having nine or more years of classroom teaching experience. Expert panel members were purposely sampled based on their knowledge and experiences administering USNS. Over 93% of the expert panel had administered USNS more than 20 screeners in their experience, indicating familiarity with the K-5 screeners. Survey questions included both quantitative (i.e., Likert scale) and qualitative items. Quantitative items used a four-point Likert scale to measure panel members' view that USNS aligned to number sense concepts. Additionally, expert panel members identified CCSS standards measured by USNS items. The second data source consisted of de-identified USNS student results. Student data used for this study were collected during the 2021-2022 academic year, and were used to evaluate claim 3 and claim 4.

Data Analysis: Expert Panel Survey Data

Descriptive statistics (i.e., mean and standard deviation) were calculated for all quantitative survey data. Generally, variance, as measured by standard deviation, is considered as the degree to which responses cohere similarly. Standard deviation values for this survey may be considered as low (0-0.49), moderate (0.5-0.99), and high (>1.0). Low variance indicated agreement among experts. Inductive analysis (Hatch, 2002) was conducted by two researchers. Data were initially scanned by them to remove any data that were deemed inappropriate or incomplete. At the second stage, they re-read data and reviewed it for initial codes. Memos were made to record possible ideas that seemed to highlight major ideas, and to support evidence leading towards possible themes. At the third stage of analysis, data and memos were reviewed and categorized to make initial themes. At the fourth stage, counterevidence was recorded and noted in light of the initial themes. Themes with a preponderance of evidence and minimal counter evidence were retained for further analysis. Quotations were used to contextualize themes and situate findings.

Data Analysis: Student USNS Data

Quantitative data were examined using Rasch (1960/1980) measurement, which constructs a linear statistical model from observed counts and categorical responses (Wright & Stone, 1999). Separation and reliability indices were used to examine the overall functioning of the USNS (i.e., claim 3). Put simply, separation and reliability can be thought of as an indicator of clarity in measuring the construct of number sense. Person separation reflects how well items separate test-takers' performance. Item separation reflects how well a sample of people separate item difficulty. In other words, person-separation values indicate a hierarchy of person ability whereas item-separation indicates a hierarchy of item difficulty. Higher values indicate better separation. Person reliability indicates consistency in how people with similar ability levels perform. Item reliability indicates consistency in item difficulty (or item performance). Reliability and separation indices are respectively classified as excellent at 0.90 and 3.0, good at 0.80 and 2.00, and acceptable at 0.70 and 1.50 (Duncan et al., 2003).

Regarding claim 4: Item fit and point-biserial statistics were used to examine the degree to which USNS assessment items measure a single construct. Item fit statistics and point-biserial correlations are appropriate indicators because "the unidimensionality requirement is satisfied when the data fit the model" (Smith, 1996, p. 26). Effective item fit is observed when the "Infit" and "Outfit" mean square (MNSQ) statistics lie within the range from approximately .5 to 1.5, and the standardized Z-statistics (ZSTD) lie within the range from approximately -2.0 to +2.0 (Linacre, 2002). Point-biserial correlations assess item quality and measure how items function in relation to one another. Correlations range from -1 to 1. Items producing a negative point-biserial are a concern and should be considered for removal from the analysis because such items fail to represent the construct being measured. Varma (2006) suggests good items have point-biserial correlations greater than 0.25. These parameters were examined for each K-5 USNS assessment.

Results and Discussion

Claim 1: USNS assess K-5 students' number sense in ways that are aligned to the Common Core State Standards for Mathematics

Validity evidence based on test content supports the claim that USNS assess K-5 students' number sense in alignment to the Common Core State Standards for Mathematics (CCSSM). The expert panel strongly agreed that the assessments reflect number sense topics, as seen by the mean score of 3.62 units on a four-point scale. Variance was low ($SD = 0.49$), which indicates substantial agreement across the panel members. Qualitative feedback confirmed the quantitative results. "[USNS] confirms students' understanding of foundational concepts with place value, whole number operations and fractions that will allow the student to progress on to new grade level content in those domains." Another respondent wrote: "Most problems involve assessing if students are flexible with how they mentally compute." Furthermore, expert panel members indicated that USNS items are aligned to the CCSSM. Respondents noted a strength of the kindergarten USNS was a focus on standards primarily located in (1) Counting and Cardinality and (2) Operations and Arithmetic. Alignment between USNS items and CCSSM was consistent across grade levels.

Claim 2: USNS are effective formative and progress-monitoring assessments; data can be used to interpret student growth between time periods

Validity evidence based on consequences of testing support the claim that USNS are effective formative and progress-monitoring assessments; data can be used to interpret student growth between time periods. A consistent theme from qualitative analysis of survey data illuminated a finding that the USNS screeners provided useful information about K-5 students' number sense. As one teacher indicated, "We use them 3 times per year to help us make MTSS [multi-tiered systems of support] decisions." A second panel member added that "teachers plan small group assessments… that align [with] curricular materials as well as different intervention programs." These comments, as well as others, indicated that the K-5 USNS are useful for learning about K-5 students' number sense, which aligns with their intended use.

Similarly, a consistent theme drawn from qualitative analysis indicated that the USNS materials provide information that can inform who may need further instructional intervention or follow-up assessments. One panel member reported that "The screeners are our primary form of data for all our data meetings in K-2." Another panel member reported that "We input data into our district platform and use the data output to group students…as well as looking at trends and needs by question type". These comments were indicative of the theme that data were used in ways to support instruction throughout an academic year because they provide a measure of growth during the academic year.

Claim 3: USNS grade-level assessments demonstrate effective construct development to measure students' number sense

Validity evidence based on internal structure supports the claim that USNS grade-level assessments demonstrate effective construct development to measure grade-level students' number sense. Rasch separation and reliability indices are reported in Table 2. Person separation and reliability range from good to excellent for each grade-level assessment series (Duncan et al., 2003), indicating that each grade-level assessment series effectively distinguishes between variations in students' number sense. Item separation and reliability statistics are respectively classified as excellent for each USNS grade-level assessment series, suggesting (a) USNS assessments demonstrate effective construct development, and (b) assessment items possess an appropriate hierarchy of item difficulty.

Table 2

Separation and reliability statistics for each grade-level assessment series

	Persons		Items	
	Separation	Reliability	Separation	Reliability
Kindergarten (*n* = 1,453)	2.36	0.85	14.42	1.00
Grade 1 (*n* = 1,675)	2.16	0.82	11.45	0.99
Grade 2 (*n* = 1,524)	2.79	0.89	14.08	0.99
Grade 3 (*n* = 1,408)	3.33	0.92	14.98	1.00
Grade 4 (*n* = 1,140)	3.45	0.92	13.63	0.99
Grade 5 (*n* = 319)	3.80	0.94	8.16	0.99

Claim 4: USNS assessment items function reasonably well in collectively measuring a single construct (i.e., number sense)

Validity evidence based on internal structure supports the claim that USNS assessment items function reasonably well in collectively measuring a single construct (i.e., number sense). Across all 212 USNS items, point biserial correlations ranged from 0.35 to 0.78, suggesting assessment items work together in measuring a single construct. Nine of the 212 USNS items were flagged for exceeding Mean square (MNSQ) and Z-standardized (ZSTD) fit-statistic parameters. Each of these 9 items possessed MNSQ values between 1.5 and 2.0, which Linacre (2002) suggests is unproductive but not degrading to the measurement model. No other items were flagged for exceeding multiple parameters, supporting the claim of unidimensionality.

Implications

This validation study evaluates four claims inherent to using the USNS as a formative and progress monitoring assessment measuring K-5 students' number sense. Relative to these claims, we present validity evidence based on (1) test content, (2) consequences of testing, and (3) internal structure. Evidence of reliability is also reported alongside validity evidence based on internal structure. Validation is an ongoing process (AERA et al., 2014), and additional validity evidence, particularly evidence of response processes and relations to other variables, would strengthen the argument supporting the use of USNS to measure K-5 students' number sense. However, results presented in this study support the use of K-5 USNS as formative assessments and progress monitoring tools as a part of classroom instruction. Teachers may confidently use the open-source USNS as a part of their instruction and assessment practices to draw detailed inferences of student knowledge and ability, and use this data to support students' individual learning needs.

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YEAR-LONG TEACHING RESIDENCY FOR STEM TEACHER CANDIDATES: PROGRAM PLANNING AND IMPLEMENTATION

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Abstract

One year residency programs are not common in secondary programs due to the nature of the degree requirements, especially a paid opportunity. The researchers on this project are implementing a year-long residency for students pursuing teaching in a STEM field, specifically mathematics, biology, chemistry, and physics. In this case, there have been modifications on the program over the past several years allowing the change. We outline the steps taken and the challenges faced when planning and implementing this pilot program.

Keywords: yearlong residency, teacher preparation, pilot

Introduction

School districts across the nation are challenged with the issue of a secondary STEM teacher shortage and a decreasing number of teacher certificates in secondary STEM fields being awarded (Feder, 2022). To recruit and retain mathematics and science majors seeking secondary teacher certification, we revised our undergraduate program to include a year-long teaching residency rather than one semester of student teaching. While undergraduate teacher preparation programs have better retention rates than post-baccalaureate and alternative certification routes (Texas Education Agency, 2022), undergraduate students often face issues with participating in an unpaid student teaching semester. Due to changes in state policy, year-long teaching residents are now allowed to be compensated by participating school districts, providing an opportunity for extended teaching residency as well as income for teaching residents.

Objectives/Purpose

In this paper, we outline the steps of transitioning our secondary STEM education program from one-semester of clinical teaching to a full year. STEM majors within this pilot program include mathematics, biology, chemistry, and physics. While this program does not include all STEM fields, we use the acronym STEM for brevity. In addition, we highlight the successes and challenges during the planning and implementation of this pilot program. While our previous model was successful, a year-long teaching residency would provide our secondary STEM teacher candidates opportunities for extended field experiences that includes both first and last days of a K-12 school year, as well as compensation for their time. Historically, student teaching experiences have been unpaid. Because of this, residents often have to work additional jobs during their student teaching semester. This can be challenging for the teacher candidates, and can cause them to choose alternative routes to teaching or choosing other career fields. The purpose of this practitioner paper is to share our process, successes, and challenges when planning and implementing a year-long teaching residency program for secondary STEM teacher candidates.

Theoretical Framework and Related Literature

According to Lave and Wenger's idea of situated learning (1991), learning best occurs through a community of practice. A community of practice provides a space where individuals can learn together through shared and common interests. Through repetition and daily exposure to an environment, individuals will learn about the intricacies of teaching beyond what can be learned from theory or a textbook. More importantly, Lave and Wenger emphasized the importance of apprenticeships, in which newcomers learn from expert mentors through meaningful experiences. Specifically, during field experiences, a novice teacher is learning from the community of experienced teachers (Fields et al., 2019). An immersive student teaching experience is critical to the success of future teachers (Brown, Myers, & Collins, 2021, Darling-Hammond, Chung & Frelow, 2002), and therefore we used situated learning as our theoretical lens when planning and implementing changes to our secondary STEM certification program.

While there is agreement that teacher candidates need concrete examples and specific guidance, experience is still considered the most vital component of learning (Korthagen, 2010). Through field experience, guidance from a mentor, and university coursework, a year-long opportunity would provide the integrated approach to teaching pedagogy. Rather than completing all course work prior to field work, Fields and colleagues (2017) found both pedagogical knowledge and skills can be learned and practiced through active participation in earlier field experiences.

Theory and research support the concepts of experiential learning, communities of practice, and promotion of theoretical knowledge, but little research examines the impact of compensation for student teachers. Traditionally, student teachers are required to complete unpaid internships and educator preparation program (EPP) faculty and staff recognize this as a barrier for student teachers to overcome. While there is little research on paid clinical teaching, researchers have found that scholarships and compensation for internships do alleviate financial burden and impact undergraduate STEM students (Whitfield et al., 2021; Worsham et al., 2014). Whitfield and colleagues found an interest in teaching as the primary motivation for science majors to choose an informal teaching internship, but that compensation served as the most common secondary reason, leading us to find opportunities for paid teaching residencies.

Innovation

Change over Time

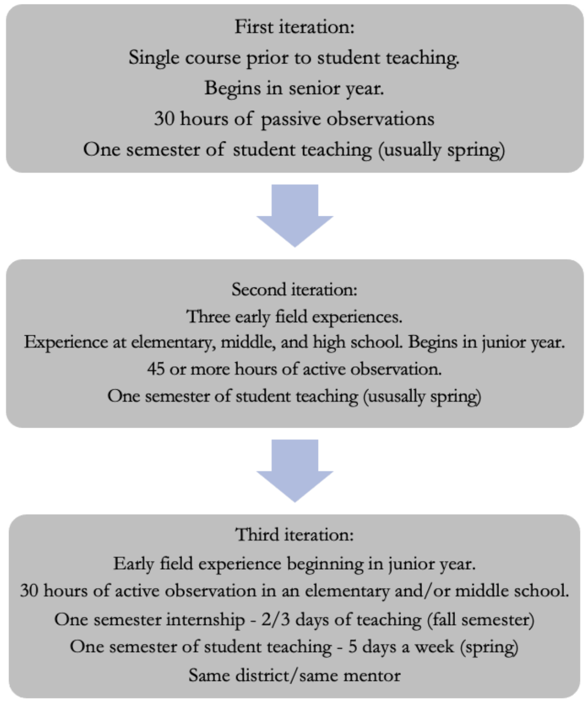
Our university's elementary and middle level programs have used a year-long teaching residency model for several years, and began offering paid student teaching opportunities recently due to changes in state policy and funding opportunities for school districts. Teacher candidates seeking certification in secondary STEM teaching fields did not have the same opportunities for paid residencies, because they only completed one semester of clinical teaching. Year-long residency requires admission to the program earlier; therefore, students must meet requirements earlier. In this section, we will begin by describing how coursework and field experience looked prior to this change. Next, we will discuss the steps we took to make those changes.

Over the past eight years, the development of our STEM program has undertaken many changes. Prior to 2014, the teacher candidates pursued their respective degrees in math, biology, chemistry, or physics, then added on teaching as a concentration. This means, the prospective teachers took a single pedagogy course, then went directly into student teaching the following semester. With retention rates a concern in secondary STEM teaching, the program reviewed other preparation programs across the states.

In 2014, a pilot program for secondary STEM began that resembled the UTeach model (Uteach Institute, 2023). UTeach has a series of six courses, yet our program only added three additional secondary education courses. Each department in the College of Science and Engineering was willing to make space for the change. With these three courses, we were able to infuse field experiences with the local school district, beginning with elementary in the first course, middle school in the second course, and high school in the final course. All of these courses were taken prior to a full semester of student teaching, which is the single constant in all phases of the program. From the first iteration to the second, students were able to gain invaluable experiences they had not had before. In Figure 1, we highlight the key program changes over time.

Figure 1

Flow Chart of Basic Changes in the Program Over the Years



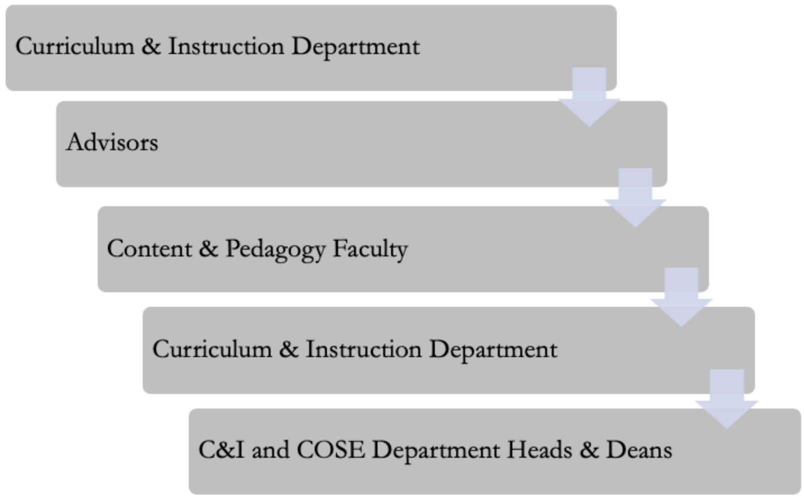
However, as the profession and state requirements continue to change, we are willing to evolve and make changes to the program as needed. With the new opportunity for paid teacher residencies, we collaborated with stakeholders across our department, university, and school district partners to transition our secondary STEM undergraduate teaching programs to a year-long teaching residency. This change will be piloted with four teacher candidates who will begin Fall 2023 as interns and Spring 2024 as residents, providing them with a paid, year-long teaching experience.

Steps for Planning Implementation

As one can imagine, many meetings among many different groups had to take place prior to implementation. First, within the department of Curriculum and Instruction, the key faculty along with the department head brainstormed by reviewing programs at other universities to determine best practices and potential outcomes. With several districts offering a financial incentive for the one-year, we believed an adjustment of our early field-based courses to the first semester of senior year could provide for the needed extended field experience. Because we have more secondary education courses in our STEM program compared to other secondary programs, we chose to pilot this change with our STEM majors. As noted by Figure 2, you can see the flow of the meeting schedule, which occurred during the early part of a fall semester.

Figure 2

Meeting Flowchart



After meeting with key faculty in Curriculum and Instruction, we met with advisors to discuss degree plans and order of coursework. The advisors provided guidance on if and when various courses could be moved to different semesters of the degree plan and any prerequisite challenges. Advisors were also familiar with courses that were traditionally offered in the evenings or online that could be taken concurrently with the internship (first semester of student teaching) semester. No new courses were added or existing courses eliminated to the degree plans. Instead, our existing secondary education courses were moved to the senior year, so the only changes to the degree plans were when students took courses.

STEM content and secondary pedagogy faculty met to share the proposed changes to the sequence of coursework. During this time, we discussed courses that needed to be changed to evenings or online. The content faculty were eager and willing to make necessary changes. For example, one mathematics professor changed her course to late afternoon in order for the teacher candidates to complete field experience during the school day.

After meeting with faculty across campus, we met again with Curriculum and Instruction faculty and leadership to discuss our recommendations from the previous working groups. We also began brainstorming the pre-requisites and curriculum from the courses to scaffold across the pre-internship, internship, and student teaching. We revised learning outcomes and course descriptions of the secondary education courses. Finally, we took our proposal to the College of Science and Engineering department head meeting hosted by their dean. The Curriculum and Instruction faculty and department head shared the proposed changes and answered various questions. We ensured that all stakeholders at every level were in agreement on the program changes.

Once the program took shape and final decisions were made, we collaborated with K-12 district administrators who were offering the year-long paid teaching residency. In these meetings, we discussed our teacher candidates' needs, their district needs, as well as their requirements for participation in the paid program. The two districts were eager to host STEM teacher candidates, and were flexible and willing to make adjustments.

Program & Classroom Examples

Challenges

During the planning and implementation of this pilot program, we discovered several road bumps like admission to the educator preparation program, scheduling of content coursework and field experience, and limited options of cooperating school districts that offered monetary compensation for teaching residents. Each of these hiccups encouraged us to work with stakeholders to be creative while still offering our teacher candidates the best education and experience. Initially, we had overlooked the requirement that our STEM clinical teaching residents would need to be fully admitted into the EPP prior to their year-long residency per state policy. In the planning, we assumed teacher candidates could continue to take an online reading course the first semester of residency (first semester of senior year). However, the reading course is a prerequisite to admission to the EPP and not all of our year-long residents were admitted to the EPP. We thought we had planned with all necessary stakeholders, but now recognize the importance of including advising staff from the teacher certification office when making these changes. The teacher candidate who was not yet admitted had to appeal to an appeals committee for permission to take the reading course concurrently with their residency coursework.

While our elementary and middle level programs have used the year-long residency model for several years, the secondary program had not because secondary teacher candidates are still typically taking courses in their content area the first semester of their senior year, making it more challenging to require at least 2.5 days per week of field experience. Our revised degree plans continued to allow for content coursework in the various STEM majors that first semester of residency, but we (Curriculum and Instruction faculty) had no control over when the courses in those content areas would be offered during the day. Our planning with the STEM advisor reduced the number of issues, but our mathematics teacher candidates in the pilot program had to take a required Monday, Wednesday, Friday class during their first semester of residency. This prevented them from meeting the required numbers of hours identified by the school district to earn payment. One district was flexible in this requirement while the other proposed the teacher candidate would be paid only for the second semester of residency.

Another challenge we faced was the location of the cooperating districts who were able and willing to compensate our teacher candidates for their residency. The two school districts were awarded funding through the state to develop a sustainable way to provide pay for clinical teachers. These districts were essential to the success of this program and the transition. However, the cooperating districts ranged from 30 to 65 miles from our main university campus. We are in a rural area, but mostly larger districts are doing the paid residencies. This caused difficulties for the teacher candidates who had daytime classes, because they were expected to return to their secondary campus after taking their university coursework. This situation was not ideal, but the teacher candidates in our pilot program were willing to drive to these districts. The alternative would have been for the teacher candidates to complete their residency in a closer school district without compensation.

Successes & Opportunities

A major success is that the departments worked well together. There was no dissension, but rather a total agreement change was necessary to ensure the best program options for our students. Faculty, staff, and administrators agreed on the benefits of a year-long teaching experience with compensation. Candidates would be able to experience the first days of school until the final days of school, rather than missing one of those important parts of the year. One semester candidates may only experience a heavy testing season, which can hamper their experiences of curriculum and teaching opportunities. They see more lessons revolving around review, rather than lessons taught. Stakeholders also agreed this model allows for teacher candidates to implement more instructional strategies and receive extensive feedback from supervisors and mentors.

Another success noted in the program is within the partnership with the districts. Each district interviewed the candidates, which emphasized the importance of this as a job. The candidates were exposed to the professional aspects of the career prior to beginning their year-long journey. The districts have included the teacher candidates in all communication beyond the interviews. With the change to more time in the schools, each candidate will become part of the community of the school from the beginning, including teacher in-service days.

Implications

We needed buy-in from the STEM content department faculty and administrator, as well as faculty and leaders in education. We also considered the needs of our students when implementing this pilot program. Our students were flexible and enthusiastic about the changes, but they also recognized our willingness to be flexible to implement this program and meet their needs. When considering changing to a year-long residency for secondary programs, we would advise others to pilot one or two content areas prior to making changes across multiple content areas. Challenges and barriers may exist for secondary because of content courses in senior year and distance of cooperating districts. However, with open communication between departments and key stakeholders, change is possible. While we are unsure of actual results, the four prospective teachers and the districts have voiced their excitement to be part of the pilot program. Our future research will include interviews, efficacy scales, and pre-post tests on pedagogy to determine the outcomes of a year-long experience as compared to three isolated field experiences. Beyond the research, we plan to explore other funding opportunities from this pilot program and research study.

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CONNECTING EXPERIENCES IN MATHEMATICS AND MATH TRAUMA

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Abstract

Colloquial use of the phrase 'math trauma' is common among mathematics and mathematics education communities, but it has been unclear whether 'math trauma' can truly be considered a form of 'trauma'. To determine if that is the case, first, widely-accepted clinical definitions of trauma were analyzed to conceptualize a general definition of trauma. The resulting closed codes were applied to student responses collected from a mathematics content course intended for early-childhood/elementary education majors through the regular course of classroom assignments. Results indicated that math trauma can be considered trauma by some clinical definitions and that student experiences are pervasive and apparent across event time scales, threat loci and sources, and responses.

Keywords: mathematics education, research, trauma

Introduction

Mathematics educators employ the phrase "math trauma" often to describe an emotional response witnessed in their students when learning concepts known to be historically difficult or when asked about previous experiences with mathematics and mathematics learning (Ruef, 2018a; Ruef, 2018b). A similar emotional response might also be observed when talking to students' parents, school administrators, or even when meeting friends and acquaintances outside of professional settings (Boaler, 2015).

Educational practice has recently expanded to consider appropriate classroom practice when working with students who have experienced trauma (Brunzell, et al., 2016; Chafouleas, et al., 2019). The combination of these experiences using the phrase "math trauma" and a burgeoning awareness of how educational practitioners can utilize trauma-informed pedagogical practices suggest that a connection between them may lead to ways to recognize, mitigate, or even prevent the experience of "math trauma" in mathematics classrooms.

Objectives of the Study

The ubiquitous usage of this phrase "math trauma" and the potential impact of being able to identify its causes and effects prompt further inquiry. To determine whether the concept considered colloquially as "math trauma" might actually *be* trauma, this study explored the current information found in extant literature regarding math trauma, analyzed the possibility of a connection between shared student experiences and a more common concept of trauma, and then analyzed commonalities among experiences shared by students. If it is indeed possible to draw a connection between these student experiences and accepted ideas about trauma, it will be imperative to investigate this relationship further to better understand it; if it is not possible, however, it will be incumbent upon practitioners to cease using the term.

Related Literature

Trauma

Trauma psychology is a new and growing field in psychology that is still undergoing periods of definition and redefinition as practitioners and researchers determine its true purpose (Dalenberg, et al., 2017). Defining the construct of trauma began as the need for a reliable and valid diagnosis of Post-Traumatic Stress Disorder (PTSD) arose from its inclusion in the Diagnostic and Statistical Manual of Mental Disorders (DSM) beginning in 1980. The criteria for diagnosing PTSD have undergone many changes since its inclusion in DSM and more recent research in the field of traumatology indicates that a more general definition of trauma, uncoupled from a PTSD diagnosis, may be necessary as it is clear from clinical practice that individuals do experience significant distress in response to events considered “low-magnitude stressors” (Dalenberg, et al., 2017, p. 19).

This evolution of the construct of trauma has led clinicians to utilize a “meaning of trauma that is defined by the individual’s understandings and cognitive (as well as emotional) reactions to the [traumatic] event” (Dalenberg, et al., 2017, p. 23). This more personal construct of trauma creates limitations in developing generalizable lists of potentially traumatic events and precludes current trauma instruments as evaluation tools but may allow those outside of diagnostic settings to broaden their ideas about which experiences may be perceived as traumatic. This broadened concept allows the inclusion of those events that may be perceived threatening to one’s "foundational beliefs about self and the world” (Dalenberg, Straus, & Carlson, 2017, p. 24), like a crisis of identity or self-efficacy, in addition to those that are more obviously traumatic, like being the victim of violence or natural disaster.

Math Trauma

A systematic search using the multi-database search engine available through the university library was conducted in spring 2023. First, a keyword search was performed using the queries “math*” and “trauma*”. This search yielded a vast number of results (12,014). Limiting this same search by searching only for peer-reviewed articles narrowed the field to 9,810 results. A further narrowing to "education" as the subject resulted in 335 peer-reviewed articles. These 335 articles were subjected to a title reading for relevance, which greatly reduced the relevant literature to eleven articles (see Table 1; these results are indicated with †). Then a title search was conducted with the terms "math*" and "trauma*", which yielded 138 results; limiting to peer-reviewed articles narrowed the results to 109. After a title reading, four were relevant but one was duplicated from the previous search (indicated with ‡ in Table 1). A final search was conducted using the phrase "math trauma" in any field which yielded three more results (indicated with ^ in Table 1) at which point the 17 articles were subjected to a close read. This reading, along with snowballing, provided four more articles for a total of 21.

Table 1

Citations of literature included in this review (alphabetical).

†Adamuz-Povedano, N., Fernández-Ahumada, E., García-Pérez, M.T., & Montejo-Gámez, J. (2021). Developing number sense: An approach to initiate algebraic thinking in primary education. *Mathematics* (Basel), 9(5), 1–25. https://doi.org/10.3390/math9050518

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†Engelbrecht. (2010). Adding structure to the transition process to advanced mathematical activity. *International Journal of Mathematical Education in Science and Technology*, 41(2), 143–154. https://doi.org/10.1080/00207390903391890

‡Faradillah, & Febriani, L. (2021). MATHEMATICAL TRAUMA STUDENTS' JUNIOR HIGH SCHOOL BASED ON GRADE AND GENDER. *Infinity* (Bandung), 10(1), 53–68. https://doi.org/10.22460/infinity.v10i1.p53-68

†Garcia-Olp, Nelson, C., & Saiz, L. (2022). Decolonizing Mathematics Curriculum and Pedagogy: Indigenous Knowledge Has Always Been Mathematics Education. Educational Studies (Ames), 58(1), 1–16. https://doi.org/10.1080/00131946.2021.2010079

†Kokka, K. (2019). Healing-Informed Social Justice Mathematics: Promoting Students' Sociopolitical Consciousness and Well-Being in Mathematics Class. *Urban Education* (Beverly Hills, Calif.), 54(9), 1179–1209. https://doi.org/10.1177/0042085918806947

†‡Lange, & Meaney, T. (2011). I actually started to scream: emotional and mathematical trauma from doing school mathematics homework. *Educational Studies in Mathematics,* 77(1), 35. https://doi.org/10.1007/s10649-011-9298-l

†Maciejewski, W. (2021). Teaching math in real time. *Educational Studies in Mathematics*, 108(1-2), 143–159. https://doi.org/10.1007/s10649-021-10090-9

‡Matthews, L.E. (2018). He Who Feels It, Knows It: Rejecting Gentrification and Trauma for Love and Power in Mathematics for Urban Communities. (2018). *Journal of Urban Mathematics Education*, 11(1&2).

†McGee, E.O. & Pearman, F. A. (2014). Risk and Protective Factors in Mathematically Talented Black Male Students. *Urban Education* (Beverly Hills, Calif.), 49(4), 363–393. https://doi.org/10.1177/0042085914525791

Noguchi, S. (2015). Hate math? It's not about you, and new teaching methods may help. *Oakland Tribune* (18 Mar 2015).

^Owen, Sarah, E. (2021). An exploration of math trauma through ability grouping and teacher language in elementary schools. *Honors Projects* (Seattle Pacific University). 129.

†Page, A. (1994). Helping students understand subtraction. *Teaching Children Mathematics*, 1(3), 140–143. https://doi.org/10.5951/TCM.1.3.0140

^Ruef, J. (2018a). Think you're bad at math? you may suffer from 'math trauma'. The Conversation. Retrieved September 22, 2022, from https://theconversation.com/think-youre-bad-at-math-you-may-suffer-from-math-trauma-104209

Ruef, J. (2018b). How to help students heal from 'math trauma' (opinion). Education Week. Retrieved September 22, 2022, from https://www.edweek.org/teaching-learning/opinion-how-to-help-students-heal-from-math-trauma/2018/11

†Rufo, D. (2017). Math Hater: How One Child Overcame Her Math Anxiety Through Self-Administered Art Therapy. *Art Education* (Reston), 70(5), 6–10. https://doi.org/10.1080/00043125.2017.1335527

†Shi, Z. & Liu, P. (2016). Worrying thoughts limit working memory capacity in math anxiety. *PloS One*, 11(10), e0165644–e0165644. https://doi.org/10.1371/journal.pone.0165644

‡Strogatz, S. (2014). Writing about math for the perplexed and the traumatized. *Notices of the American Mathematical Society*, 61(3), 286–291. https://doi.org/10.1090/noti1086

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†Ziols, & Kirchgasler, K. L. (2021). Health and pathology: a brief history of the biopolitics of US mathematics education. Educational Studies in Mathematics, 108(1-2), 123–142. https://doi.org/10.1007/s10649-021-10110-8

In the review of this literature, the vast majority either did not address the concept of math trauma directly or used the phrase interchangeably with math anxiety. In any case, those that did specifically address math trauma did so anecdotally. Two definitions of math or mathematical trauma arose. The first was from Lange and Meaney (2011), who claimed that "…being deprived of opportunities for expression, interpretation and agency in relation to mathematics and hence positioned as passive receivers of superficial mathematical knowledge amounts to *mathematical trauma*" (p. 38, emphasis in original). The other attempt at definition came from Reuf (2018b), where it is claimed that "in its worst manifestations, math anxiety becomes what my colleagues and I call math trauma—a form of debilitating mental shutdown when it comes to doing mathematics" (para. 1). Unfortunately, neither of these definitions are linked to clinical, accepted conceptions of trauma nor were they determined through rigorous study of how one might experience math or mathematical trauma.

Methodology

Given the relative dearth of empirical information regarding math trauma in the field of mathematics education, it is essential that a link, if it exists, be drawn between the experiences of students in mathematics classrooms and the debilitating response to learning mathematics some experience. The search for an 'existence proof' of this link is what motivated this study and the following research questions:

1. How does the literature describe the general concept of trauma?
2. Can experiences that students share about their mathematics education be linked to the general concept of trauma?
    a. If a connection is found, what are the themes in those experiences that students share?

A General Concept of Trauma

Lacking a working definition of math trauma or mathematical trauma leads back to the concept in clinical psychology. As discussed previously, current theoretical work in trauma psychology is still ongoing around how to define the concept of trauma, but there are descriptions used in practice. In working to determine the conception that may apply to the idea of math or mathematical trauma, definitions that are commonly used in educational settings for non-diagnostic purposes were analyzed. (e.g., American Psychological Association, n.d.; Brunzell, Stokes, & Waters, 2016, p. 64; National Child Traumatic Stress Network, n.d.; Substance Abuse and Mental Health Services Administration, 2022).

Connecting Shared Student Experiences with Concepts of Trauma

The data used in this study to determine the existence of a connection between student experiences and the general concept of trauma resulting from our initial analysis were collected from open-ended student responses to prompts (see Table 2) in a required mathematics content course intended for early-childhood and elementary education majors during the regular course of study from Fall 2020 through Spring 2022. All students enrolled in the course were majoring in early-childhood or elementary education at a regional institution in southern New England; this course is a prerequisite for acceptance into the university program which leads to licensure for teaching pre-kindergarten through sixth grade in the state. The course was taught online during Fall 2020 and Spring 2021 and in person for Fall 2021 and Spring 2022.

Responses that could still be accessed using the online Learning Management System (LMS) were downloaded before being copied and pasted verbatim into one collated document with all identifying information removed. There were 85 responses available for the first prompt and 63 available for the second prompt.

Table 2

Prompts from which data were collected

Prompt	Assignment	Number of Responses Collected, *n*
"Write a few sentences describing your experience with mathematics and how you see yourself as a learner of mathematics."	Homework #1, Question 1	85 (Fa20 32, Sp21 32, Fa21 17, Sp22 4)
In preparation of our discussion about addition math facts and the arithmetic properties, I'd like you to read the short article entitled "Fluency without Fear" by Dr. Jo Boaler. Then, please answer these questions: 1. What was your experience as a student with "fact fluency" (either addition or multiplication)? 2. How is what Dr. Boaler proposes in the article the same or different than your own experience?"	Discussion Prompt	63 (Fa20 32, Sp21 31)

Research Methods

To address the first research question, the four definitions of trauma were analyzed using thematic analysis (Braun & Clarke, 2006) to determine the closed codes with which to analyze the open-ended student responses. Throughout this process, the authors discussed any discrepancies that arose and worked to reach consensus. For the second research question, analysis began with the 85 responses to the first prompt with each author using the closed codes determined in analysis of common definitions of trauma. After the initial coding process, the authors discussed any differences between them until agreement was reached on the responses considered. This process was repeated with the 63 responses to the second prompt. Finally, instances that were identified as potential math trauma were subjected to another thematic analysis (Bruan & Clarke, 2006) by each individual author and then to form consensus in order to address the final research question.

Results and Discussion

After a thematic analysis (Braun & Clarke, 2006) of these definitions and discussion, the authors agreed that, in general, definitions of trauma relate to an *event*, a *threat*, and a *response*. Theming work done in trauma psychology corroborates this generalization (Dalenberg et al, 2017). In this case, an *event* is a situation recalled by an individual that caused a *threat*. This *threat* could be to one's life or physical safety but could also be threatening to one's "foundational beliefs about self" (Dalenberg et al, 2017, p. 18), and leads to some *response* in emotion or through assimilation of new information into one's foundational beliefs.

The closed coding of student responses resulted in twenty-one instances which shared relevant, related *event, threat*, and *response*. Before in-depth results are shared, it should be noted that student responses analyzed in this study were not originally collected with the intent to be studied for this purpose which is an obvious limitation of its use in analysis. This data, collected through the regular course of classroom practice, was chosen for analysis in connection to the general concept of trauma because of the organic findings of a pattern which seemed essential to interrogate. It is noteworthy that out of 148 shared responses from students there were 21 instances of related *event*, *threat*, and *response*. In other words, over 14% of responses had connections to a concept of trauma without being prompted to share it specifically and as such, it seems clear that there *is* a connection between student experiences in learning mathematics and accepted uses of the concept of trauma; students do experience clinical trauma centered about mathematics.

To understand similarities and differences among the 21 instances of potential math trauma, the authors performed a second thematic analysis across the identified *events*, *threats*, and *responses*. Themes and paraphrased examples are shared in Table 3 (due to the sensitive nature of these shared experiences, direct quotes will not be shared in this manuscript). The *events* students shared were temporally bounded. Some occurred only once (one-time) while others happened throughout a course or grade level (class) or were pervasive through several courses or grade-levels (pathway). The *threats* shared from student experiences were of internal or external locus. Internal threats were from two sources, self or peers; these occurred when the event threatened a student's perception of themselves (internal self) or how they perceived their peers (internal peer). External threats were similarly sourced; these either threatened how the student was perceived by an authority figure like their teacher (external self) or how they were perceived by their peers (external peer). Some students shared threats that were from multiple sources. Finally, in analyzing the *responses*, four themes were found: avoidance, efficacy, identity, and emotion. An avoidance response is one where the student shared that after the event and threat, they made conscious choices to avoid mathematics or mathematical situations in the future; an efficacy response was one in which the student's self-efficacy in mathematics was greatly diminished by the event and threat; an identity response resulted in a change to the student's self-identity in mathematics; and an emotion response was one in which the student shared a visceral emotion attached to the event and threat. A student's response may be one, two, three, or all four of these types.

Table 3

Themes among instances of potential math trauma

Codes	Themes (n)		Example
Event	One-time (3)		A teacher making fun of a student or calling them out in front of the whole class
	Class (13)		Timed fact tests throughout third grade
	Pathway (5)		A student being forced into a differently-leveled mathematics course
Threat	Internal	Self (5)	A student performing at a level they considered beneath their abilities
		Peer (9)	A student performing at a level they considered beneath their peers
	Externa l	Self (5)	A student performing at a level below the expectation of their teacher
		Peer (4)	A student compared to their peers and found wanting
Respons e	Avoidance (5)		Changing majors to one that requires fewer mathematics courses
	Efficacy (12)		A student feeling as though they are incapable of doing or learning mathematics
	Emotion (8)		Feeling hatred toward mathematics or a mathematics teacher or a manifestation of math anxiety
	Identity (3)		A student no longer identifying as a "math person"

This thematic analysis aligns with the personal-meaning concept of trauma, wherein the threat from an event is to one's foundational beliefs about self and the response is congruent with such a threat (Dalenberg, et al., 2017). In these potential cases of math trauma, the event threatened the student's belief about their performance or abilities in mathematics or even being a doer-of-mathematics as a part of their identity, eliciting a response in which the student changed their behavior accordingly through an emotional reaction or alteration of their beliefs about themselves.

After themes were agreed upon and assigned to the data, frequency pivot tables were constructed to determine any emerging patterns or points of interest in order to address the second research question. In general, the frequencies were relatively equally distributed among any two categories (e.g. comparing events with types of threat or types of threat with responses; see Table 4) but two particular results are of interest. First, is the idea that some experiences of learning and doing mathematics in a single grade-level or course may compound in a way that is distressing enough to students to be considered trauma; there were fewer shared experiences of a one-time or pathway event that rose to this severity. This relatively short negative experience, when considering the number of years a student is required to learn mathematics in US schools, indicates that just one grade-level can have a lasting impact on students. Second, the most common reaction was an alteration of a student's self-efficacy. These results, in general, are congruent with our experiences as mathematics educators and mathematics education researchers in that students seem to readily depress their own beliefs about their capabilities in mathematics.

Table 4

Pivot table: Occurrences of Types of Threat compared with Response

Threat Locus	**Threat Source**	**Response**			
		Avoidance	Efficacy	Emotion	Identity
External	Authority	2	3	2	1
	Peer	2	2	1	0
Internal	Self	2	4	1	1
	Peer	0	4	4	1

It is important to reiterate here the limitations of this study. These data were collected through the regular course of classroom assignments without the express intent to later analyze it for this purpose. In addition, the relatively small sample size prevents generalization from this analysis. Even so, the case for potential math trauma presented in these student stories is clear.

Implications

The purpose of this study was to formulate an existence proof of sorts for "math trauma." The connection between shared student experiences in learning mathematics and a requisite *event*, *threat*, and *response* was demonstrated from over 14% of responses. Therefore, a definition of "math trauma" is proposed: Math trauma is the response that occurs when a person experiences an event which threatens their perceived sense of self or safety through the course of learning mathematics and results in a persistent negative change to their disposition towards the subject. Math trauma may occur as a result of a one-time event but the data also suggest that repeated negative experiences throughout a grade-level, course, or pathway may be a source of math trauma. It is probable that analysis of other sources of more purposeful data could revise this definition to one that would result in better identification, treatment, and prevention of the occurrence of math trauma in our students and classrooms.

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RESEARCHERS' EXPERIENCES WITH AFFECTIVE MEASURES IN A STEM WORKSHOP SERIES FOR TEACHERS

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Abstract

The Montana State University, MSU, Research in Action series aims to connect researchers with teachers across Montana in a way that facilitates discussion of cutting-edge work being done by local scientific researchers alongside the stories of those researchers. In designing this workshop series, we sought to support the broader impact efforts of MSU researchers, increase the pedagogical content knowledge of educators, and highlight the work of our own research center on STEM education, utilizing the e-Science Framework. This paper presents the findings regarding the role and benefits for the MSU researchers who presented at the workshop series.

Keywords: STEM outreach, affective measures, K-12 STEM education

Introduction

The MSU Research in Action Series connects teachers throughout the state of Montana with STEM researchers through a set of one-hour professional development workshops. These workshops are co-designed with a STEM researcher as well as a STEM education expert in the Department of Education. The STEM education researcher presents three constructs of interest regarding student STEM affective measures to the STEM researcher, who chooses which construct is most relative to their research endeavors or experiences in science. At the workshop, the STEM researcher first begins by telling their story of how they came to be a STEM researcher and then connects to their current work. While each workshop is presented with a single researcher, teachers are encouraged to attend multiple workshops within the series, so that they can learn about multiple constructs and hear from multiple experts in the field. Teachers are informed of the MSU STEM researchers field of research and research interests prior to registering for the workshop. The choice of constructs for the first year of this workshop series came from the work of Trujillo and Tanner (2014) who discuss the importance of affective measures in the learning of science.

Objectives of the Study

The goal of this study was to understand the experience of researchers who engage in designing professional learning opportunities for teachers related to their research interests and personal stories. We sought to understand whether the researcher's had prior familiarity with research constructs related to student affective measures and whether the experience of co-designing these short, single session professional learning for teachers will influence the researcher's future outreach efforts related to their research. Our research questions were:

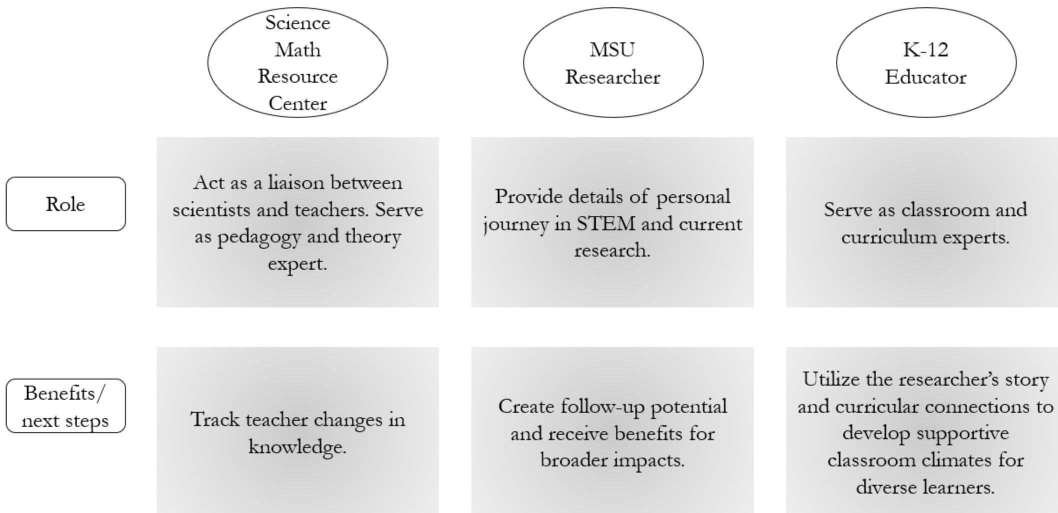
1. To what extent did participation in co-designing PD for teachers related to student affective measures and their STEM research influence STEM researcher understanding of student affective measures?
2. What are the perceived benefits for STEM researchers by participating in the Research in Action Series?
3. In what ways do researchers describe applying knowledge gained through participation in the Research in Action Series?

Theoretical Framework and Related Literature

The theoretical framework applied to understand the interactions within the workshop series is based on several scientist-teacher partnership models (Falloon, 2013; Knowlton et al., 2015; Mansour, 2015). While each of these partnership models typically details a longer connection between individual scientists and teachers, the framework presented by Falloon (2013) was used to determine the roles and activities that each stakeholder would play in the current workshop series, as shown in Figure 1. This framework identifies unique roles and outcomes or drivers for the [education outreach center], individual scientists who present a workshop, and individual teachers who attend the workshop. The current work explores the role and perceived benefits of the MSU researchers found in the center of the e-Science Framework.

Figure 1

Framework based on Falloon (2013) e-Science Framework



As seen by the variety of scientist-teacher partnership models, there are several methods of STEM outreach for scientists. Indeed, Komoroske et al. (2015) provide a practical guide to engaging in outreach to serve broader impacts work within funding mechanisms. This guide includes careful consideration of factors that can help to ensure that researchers, educators, and students all receive a benefit and to maximize that experience. This workshop series was designed to work directly with teachers so that the teacher can become more aware of the STEM affective measures construct and the timing of the workshop enabled researchers to be more flexible with time constraints during working hours.

Methodology

The workshop series was offered 5 times over the fall of 2022 and spring of 2023, with 3 of these researchers responding to a survey following their participation. Engagement in the workshop series for the researchers involved an initial outreach connection through a member of the sponsoring center and a connection to the professional development (PD) lead at the center. After the researcher agreed to present, the PD lead explained the three affective measures of interest, student STEM identity, sense-of-belonging, and self-efficacy so that researchers could choose the construct which was most relevant to them personally. The PD lead then shared research relevant to the chosen construct with the STEM researcher and was available to provide feedback and support as the MSU STEM researchers created and refined their presentations within the context of that construct. Each researcher was assigned a pseudonym for the purposes of describing individual knowledge changes in the results section, however the survey was conducted anonymously so specific sessions are not linked to the responses. The survey was designed to measure familiarity with constructs highlighted by Trujillo and Tanner (2014), which were the constructs the researchers were asked to choose as themes for their workshops. Additional open-ended questions asked researchers to describe how this might impact their future outreach or teaching efforts.

Results and Discussion

All the researchers that responded to the survey identified as white females and each researcher engaged in less than 5 outreach events each year. The familiarity with each of the constructs of interest (STEM identity, sense-of-belonging, and self-efficacy) is listed in Table 1 as well as a short description from each participant as to how their knowledge changed as a result of participation in co-designing the professional development. On average, the participants were at least somewhat familiar with all 3 constructs, but only one participant was very familiar with any of the constructs. Two of the participants reported having supported these constructs in prior work, however when asked to describe such support it was mostly broad, for instance one participant reported engaging in outreach "to encourage middle and high school students to consider STEM."

The researchers each identified ways in which co-designing the workshop changed their understanding of the constructs. Interestingly, Ann mentioned that she gained new familiarity with the terms, but she also indicated a high familiarity with at least two of the constructs before the workshop. It is possible that she either rated her familiarity after the workshop, or that her familiarity changed in a qualitative way rather than a quantitative increase. For instance, Teresa and Joan both indicate that they made a connection to their personal story due to the structure of the workshop. Researchers also indicated how they will continue to use the knowledge they gained for future STEM outreach. Ann discussed how it will guide her interactions with her own students, particularly to make them "feel welcome and heard in our interactions." Teresa mentioned wanting to become more "intentional" in her outreach efforts and fostering growth in student connection to science. Joan reported specific efforts to bring the talk to a larger audience through a summer institute. Interestingly, the researchers' responses all related to student affective measures rather than simply sharing their research.

Table 1

Participant knowledge of student STEM affective measures

Participant pseudonym	Prior familiarity of student STEM affective measures			Description of change in understanding as a result of preparing for or delivering the workshop.
	Identity	Sense of belonging	Self-efficacy	
Ann	4	5	5	Became familiar with them!
Teresa	3	3	4	My understanding increased as I learned how these terms are discussed in relation to STEM and what kinds of work and research is done in these areas. My understanding also changed as I reflected on my own relationship with these terms and how they have changed for me over my life.
Joan	2	3	2	It caused me to reframe my own experience to a certain degree.

Implications and limitations

While this is a small-scale study involving a few researchers, the design of the workshop series necessitates a small sample size. The findings indicate that the act of co-designing a workshop which presents the researcher's story contextualized within a specific affective measure helps the researchers to think more broadly about their interactions when they engage with students and outreach efforts.

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EXPLORING THE PEDAGOGY OF USING CHATGPT WITH STUDENT TEACHERS IN PLANNING MATHEMATICS LESSONS

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Abstract

This article describes the results of exploring student teachers' use of ChatGPT with lesson planning. Student teachers followed a faculty-crafted guide to prompt ChatGPT to give them lessons for teaching mathematics standards. Following the guide, they were to evaluate the results from ChatGPT and revise their prompt. At the end of the guide, they evaluated the final version of the lesson and made choices: to use the lesson for teaching, use parts of the lesson for teaching, or not use it at all in teaching their lesson.

Keywords: Teacher Preparation, Pedagogy, AI, ChatGPT, Mathematics

Introduction

In December 2022, our teaching program discovered ChatGPT. We anticipated students becoming proficient in its use and using it as a shortcut for assignments and non-research-based teaching plans (Cotton, et al., 2023). Like other teacher preparation programs, students often relied on AI and websites like Pinterest and TeachersPayTeachers for pre-made lessons (Sawyer et al., 2020). To address this issue, we integrated a curriculum literacy module into student teaching (Sawyer et al., 2020; Schroeder & Curcio, 2022). This module taught students to evaluate online ideas based on state standards, student thinking, and cultural responsiveness. Recognizing students' time wasted on aimless searches that resulted in low-quality lessons, we explored how ChatGPT could guide them in crafting selective, effective, and critically evaluated lesson plans.

Objectives of the Study

The primary objective of this study was to explore how student teachers utilized ChatGPT in planning the lessons they taught in their classrooms. The researchers sought to understand whether the student teachers followed the ChatGPT guide and created prompts aligned with standards. Additionally, they aimed to investigate whether the student teachers evaluated the results, revised their prompts, and reevaluated them until they were satisfied with the outcomes. The researchers also sought to uncover the factors that led students to revise their prompts and how student teachers utilized the lessons generated by ChatGPT after making revisions.

At the time of this study, there was a lack of research utilizing ChatGPT with student teachers. This research aimed to provide valuable insights and cases for experimentation, evaluation, and reflection on how ChatGPT could effectively support lesson planning for student teachers.

Related Literature

ChatGPT became available to the public in late November 2022, and educators had varied reactions to this large language model, which generated prompt responses within seconds. While many believed ChatGPT could serve as a valuable tool to enhance student learning and writing, others expressed concerns about potential issues of plagiarism, cheating (Cotton, et al., 2023; Sullivan et al., 2023), and academic apathy (Gordon, 2023). At the time of this study, ChatGPT was relatively new to the public, and no published studies explored its usage with student teachers.

A search conducted for this article using AI through our university library search engines, Google Scholar, and Consensus AI (a ChatGPT that exclusively searches published papers as data) yielded three studies involving ChatGPT with students. However, all these studies focused on high school students (Ali, et al., 2023; Theophilou, et al., 2023; Wardat et al., 2023), with two describing ChatGPT usage in English language learning and one in mathematics. Each of these articles emphasized the need for further research on ChatGPT in teaching and encouraged exploring educator and student reactions.

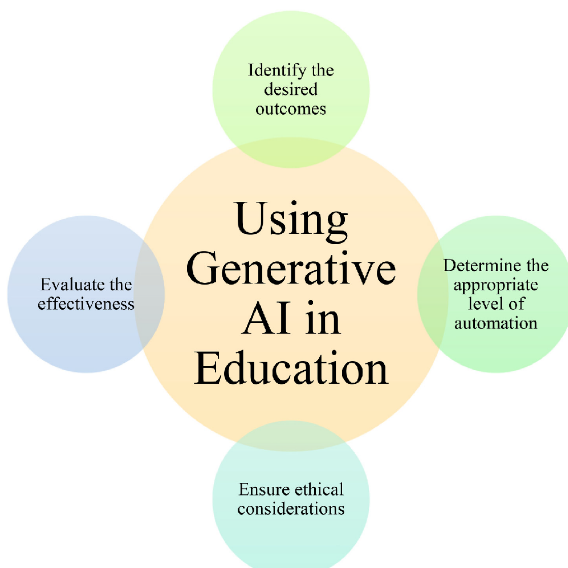
Despite concerns surrounding cheating, plagiarism, and academic apathy, the related literature also highlights numerous positive outcomes associated with the use of ChatGPT in education. We acknowledge the limitations and risks associated with ChatGPT, including biases, inaccuracies, fake information, and inequitable access. As ChatGPT continues to evolve and gain popularity, we have chosen to focus our study on positive strategies for embracing ChatGPT in teaching, as described below.

Several articles discuss the risks and opportunities of using ChatGPT (Adiguzel et al., 2023; Cotton et al., 2023; Gordon, 2023; Kasneci et al., 2023; Sok & Heng, 2023; Sullivan et al., 2023). Educators can embrace ChatGPT to save time in various ways. Firstly, it aids in creating learning assessments, including answer keys and grading (Adiguzel et al., 2023; Sok & Heng, 2023). Secondly, ChatGPT enhances pedagogical practices by designing personalized lesson plans based on student abilities, state standards, interests, and learning styles (Kasneci et al., 2023). Thirdly, it supports individualized tutoring and personalized learning experiences (Kasneci et al., 2023; Sok & Heng, 2023). Moreover, ChatGPT facilitates individualized assessments and game-based assessments with instant feedback (Cotton et al., 2023). It also proves valuable for language learners by providing feedback during the writing process, including revision and translation (Gordon, 2023; Kasneci et al., 2023). While our focus is on lesson planning enhancement, we aim to extend its use for interactive assessments and individualized tutoring for struggling student teachers in our courses.

As support for our approach with students, we offer Su and Yang's (2023) theoretical framework for applying generative AI in education called IDEE based on four guiding components (see Figure 1) designed to facilitate the use of ChatGPT and other AI in education. In this study, we used the IDEE framework to explore and analyze how students used generative AI for lesson planning.

Figure 1

Theoretical framework for using generative AI in education. Revised version of the IDEE Theoretical Framework for Using Generative AI in Education.



Methodology

This study utilized a qualitative case study approach to explore the lesson planning process of nine student teachers engaged in their student teaching, all of whom also served as paraprofessionals in their respective classrooms. The participants were pursuing prek-6th grade certification, except for one who was seeking all-level English certification. They comprised a diverse group, with two participants of Hispanic ethnicity, three White participants, two African American participants, and one Middle Eastern participant, ranging in age from 22 to 51.

The state teacher certification mandated three rounds of lessons for formal evaluation during the student teaching period. For this study, we specifically assigned the use of ChatGPT in two of these lesson rounds. To familiarize the participants with ChatGPT's functionality and its effective implementation in lesson planning, a tutorial was conducted in class, featuring models of writing prompts tailored for lesson planning. Subsequently, students were required to complete a step-by-step guide, referred to as the ChatGPT Dialogue Guide, after observing a video example demonstrating its use in planning a lesson. Students were then instructed to upload the completed guide, screenshots of ChatGPT responses, and their final lesson plans to the assignment tab for both designated lessons.

Following the posting of grades, we accessed students' files containing their work for the lessons involving ChatGPT. We meticulously recorded the contents of each student's uploaded materials (the guide, screenshots, and final lesson plan) in a spreadsheet while making reflective notes on their content.

Utilizing the IDEE framework introduced by Su and Yang in 2023, we conducted a data analysis with students as they used AI to create lesson plans. We framed the support for their engagements following the four IDEE dimensions: Identifying Desired Outcomes, Determining Appropriate Automation Levels, Ensuring Ethical Considerations, and Evaluating ChatGPT's Response Effectiveness.

Under the purview of Identifying Desired Outcomes (Su and Yang, 2023), our objective was to ascertain whether students effectively guided ChatGPT in creating, assessing, and refining lesson plans that aligned with established standards and catered to their learners' unique needs. In the realm of Determining Appropriate Automation Levels (Su and Yang, 2023), our expectations centered on students acquiring the ability to effectively instruct and evaluate the ChatGPT-written lesson through prompting and re-prompting. Concerning Ensuring Ethical Considerations (Su and Yang, 2023), we anticipated that students would address the distinctive needs of their learners when re-prompting ChatGPT. We aimed to verify that students evaluated the quality of the ChatGPT lessons by employing the same assessment criteria students used for their own student-generated lessons in previous classwork. These criteria (also in the guide itself and in course content) served as our a priori analytical codes. These codes focused on rigor/student thinking, engagement/interest, and differentiation.

It is important to note that several students did not provide complete documentation. To gain additional insights and clarification, we conducted a follow-up survey after our initial data analysis. The survey, administered in July 2023 to our graduates (who were previously our student teachers during the spring), posed questions related to the usage of ChatGPT in their lessons, the inclusion of ChatGPT-generated content, revisions made to the prompts, and their future intentions regarding using ChatGPT as teachers in the fall.

The data obtained from the follow-up survey was compared to the written responses in the guide to validate our conclusions. In addition to summarizing the data from the survey that supported our findings from students' artifacts, we also identified and addressed any contradictions in the implications section.

Results and Discussion

Following our IDEE evaluation criteria the results from student uploads of the assignment were below expectations. Due to IRB restrictions, these files could not be opened during the semester, and several students did not upload all the required documents. If all nine students completed the assigned ChatGPT task for two lessons, there would have been 18 completed guides, screenshots, and final lessons. However, the actual upload results were as follows: seven guides uploaded, 13 screenshots of ChatGPT interaction/results, and 14 final lesson plans. Notably, one student taught lesson cycle two before the ChatGPT lesson was taught, which explains the discrepancy in missing documents. When asked about the missing documents, two students responded that they did not intend to use ChatGPT for lesson cycle three, so they only uploaded documents for lesson cycle two. As previously mentioned in the methods section, we analyzed the prompts students provided to ChatGPT. The initial part of the ChatGPT Dialogue consisted of a step-by-step guide on how to interact with ChatGPT to create a prompt for an aligned-to-standards lesson plan. If students completed the guide, they could have had three iterations of prompts.

Each uploaded guide included an initial prompt for ChatGPT aligned with the state standards. Many initial prompts also included the type of lesson plan, the context for use, and a request for differentiation demonstrating the IDEE "appropriate level of automation requirement" (Su & Yang, 2023). Due to the absence of responses to their guides, screenshots of their prompts to ChatGPT were analyzed instead. The initial prompts were examined first. When comparing the lesson prompts for mathematics to those for non-mathematics subjects, we found that all but one of the mathematics lessons included only the state standard. One prompt included both the type of lesson (direct instruction) and the state standard (see Table 1 below). The remaining prompts for mathematics lesson plans did not specify the lesson type, even though the 5E lesson is emphasized for mathematics in the teacher program. Conversely, six prompts for non-mathematical lesson plans included the type (two in science and four in ELAR-English language arts reading). The only prompt including 5E was for first-grade science. Among the five prompts written for mathematics lessons, three were revised, as indicated in column three (see Table 1). In contrast, all the science prompts were revised, as were three of the ELAR prompts. The requirement to re-prompt connects to Determining the Appropriate Level of Automation in the IDEE framework (Su & Yang, 2023) as we considered how many times they prompted ChatGPT and for what reasons.

Analysis of the prompts using the a priori codes of rigor/student thinking, engagement/interest, and differentiation revealed varied differences between prompts written for mathematics lessons and non-mathematics lessons. In mathematics, three prompt revisions were made for rigor/student thinking, and one for engagement/interest. An example of this is the 4th-grade mathematics revised prompt: "Add better quality higher-order thinking questions." However, we noticed an absence of differentiation addressing language needs in the prompts for mathematics lessons. Of the science lessons' prompts, two included rigor/student thinking, two had engagement/interest, and one specifically addressed differentiation and cultural responsiveness. Often, prompts combined more than one area, as evidenced by the 6th-grade science prompt: "Revise to include differentiation, sentence stems, and higher-order thinking questions." For the revised ELAR prompts, two were for rigor/student thinking, one for engagement/interest, and two for differentiation - one targeted gifted and talented students and the other ESLs (English as a Second Language) learners. For instance, a pre-k ELAR student teacher wrote this prompt specifically targeting ESLs and different abilities of students: "Also, provide modifications: copy of notes, extra time for writing assignments, additional challenge, extra time to read, language partner, use of Google Translate, and word bank..." We concluded that this is evidence that student teachers are developing proficiency in the criteria Ensuring Ethical Considerations (Su & Yang, 2023) for their own students.

Six out of nine students responded to the follow-up survey. The results are described by question, not by subject, as we did not ask them to identify themselves or the lesson subject in the

Table 1

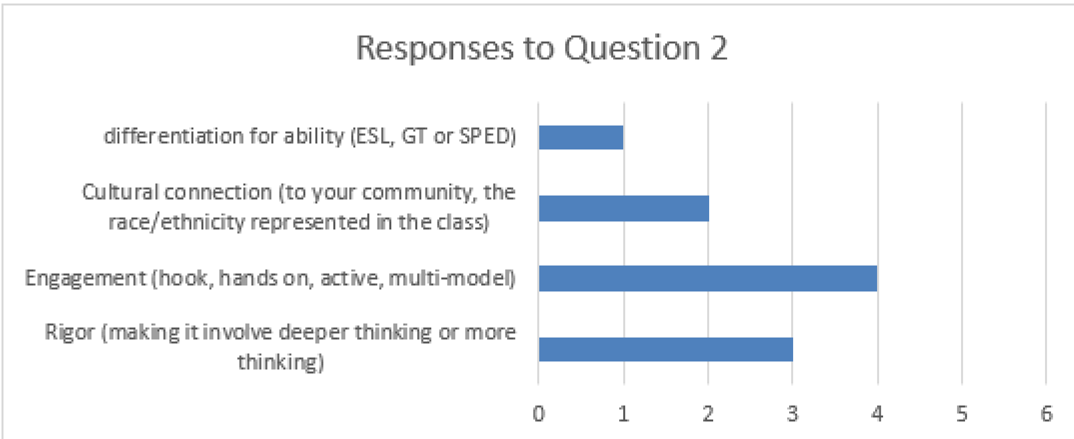
Content of prompt to ChatGPT

Subject/grade	initial prompt content	revised prompt content	final prompt revision content
math/4th	state standard	higher-order thinking questions	differentiate for ELLs and special needs
math/3rd	state standard		
math/3rd	state standard		
math/2nd	state standard, lesson type	more interesting hook and stronger closure	
math/kinder	state standard	differentiation between adding and subtracting problems	include students creating their own word problems
science/6th	state standard, lesson type, context-video, vocabulary	Spanish translation of vocabulary words	
science/6th	objective, lesson type, vocabulary	differentiation, sentence stems and high order thinking questions	make this more culturally responsive
science/1st	state standard, lesson type, specific context	adjust context, include engaging hook	create learning objective (ABCD format)
science/1st	state standard	essential questions, assessment	age-appropriate vocabulary and make intro more engaging
ELAR/8th	topic and grade		
ELAR/8th	objective, lesson type, context (the text), vocabulary, questions		
ELAR/2nd	state standard, lesson type, questions, assessment	differentiation strategies for gifted and talented	
ELAR/2nd	state standard, questions, assessment, hook, differentiation for ESL	more interesting hook and anchor chart	guiding questions for use with anchor chart, embed ESL strategies in the lesson plan
ELAR/prek 1	state guideline, lesson type, context (a specific book), vocabulary, questions for understanding, assessment	removal of an objective, change in teaching strategy, request for differentiation	vocabulary and an earlier strategy put back into the lesson plan, questions to deepen understanding
ELAR/prek 2	Topic, lesson type		

survey. Question one asked, "Did you use the information from ChatGPT for your actual lesson plan(s)? Check ALL that apply." All students confirmed the use of ChatGPT in their lesson planning. Additionally, all agreed that they used what ChatGPT provided but made some changes on their own. Five of them also agreed with the statement, "Yes, I used what it provided, but I asked it to adjust it for my learners." Question two inquired, "If you made changes to what ChatGPT provided, what were they about? Click all that apply." Four answered that they made changes to engage students, and half of them mentioned making changes for rigor. Additionally, two students responded that they made changes for cultural connections, while only one checked the answer for differentiation (see Table 2).

Table 2

Responses to Question 2 in the Follow-up Survey



The last question inquired if students would use ChatGPT for lesson planning in their future teaching. Half of them responded with a definite yes, while the other half answered maybe. Interestingly, none of the students expressed a negative response (no). For example, one student highlighted ease of use as a compelling reason for considering its future use, stating, "I might use it while working as a teacher. I found it to be quite helpful and easy to use." Another student captured the sentiment that we hoped all students would experience, stating, "Yes, I think it's helpful in creating meaningful lessons for our students without the pressure of reinventing the wheel."

Implications

Better implementation and follow-up are needed for the ChatGPT assignment. Six out of nine student teachers completed the follow-up survey and used ChatGPT. To ensure assignment completion, an alternative method for checking completion while adhering to IRB requirements should be implemented. Using a nested Evaluation of the Effectiveness criterion (Su & Yang, 2023) of student teachers' self-evaluation of ChatGPT-created products, the field supervisor should access students' ChatGPT guides to verify prompts, revisions, and subsequent checklists used on their final lessons.

Student teachers expressed a positive attitude towards using ChatGPT for future lesson planning. This willingness is likely to extend to future students as well. It is crucial for student teachers to become proficient in using AI tools, including ChatGPT, to facilitate effective and time-saving lesson planning. Educators must stay updated on the latest AI tools and include relevant modules and resources in their courses.

To achieve this, we recommend joining professional development opportunities and webinars focused on ChatGPT and AI tools for educators. We found valuable resources from websites like TCEA (Texas Computer Education Association, https://tcea.org/) and webinars such as the *ChatGPT and Generative AI in Education Series* (https://dlss.flvc.org/idn-webinars). Embracing AI may seem intimidating, but its application is user-friendly, and clearly, ChatGPT and similar technologies are becoming an integral part of education. By learning and incorporating these tools into our teaching practices, we can enhance our ability to plan effective lessons tailored to our students' specific needs. We strongly encourage educators to explore AI tools themselves, become proficient in their usage, and share these insights and tools with student teachers.

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EXPLORING MATHEMATICS PRESERVICE TEACHERS' STRENGTHS IN SMALL-GROUP INSTRUCTION DURING A SUMMER FIELD EXPERIENCE

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Abstract

The purpose of this study was to explore PSTs' experiences with instruction in a summer mathematics academy focused on the development of number sense in PreKindergarten and Kindergarten students. The participants in this study included four PSTs who taught small groups as teacher assistants under the guidance of a lead teacher in the summer before their internship (student teaching). We observed their small-group lessons twice during the academy and found they improved in the instructional areas of feedback and pacing.

Keywords: mathematics, preservice teachers, field experience, early number sense

Introduction

Field experiences are an important component of teacher education programs. These opportunities are critical in mathematics teaching, as studies have shown that preservice teachers (PSTs) report high levels of anxiety when faced with teaching mathematics (Bursal & Paznokas, 2006). Providing PSTs with structured field experiences teaching mathematics content can help improve and increase their confidence levels (Shelton et al., 2020). Developing these types of focused field experiences in mathematics can support PSTs in other aspects as well. The Association of Mathematics Teacher Educators (AMTE, 2017) emphasized the importance of opportunities for elementary PSTs to engage in clinical experiences that are specific to mathematics, children's mathematical thinking, and instruction for diverse learners. As a result, we developed a summer mathematics academy in partnership with a local school district to provide support in key early number concepts to Prekindergarten and Kindergarten students from low socioeconomic status (SES) backgrounds as an additional field experience opportunity for PSTs. Experienced lead teachers from a local school district and PSTs led the instruction in this academy. This provided PSTs with a unique opportunity to gain additional experience teaching mathematics while under the supervision of a lead teacher.

Objectives of the Study

The focus of these proceedings center on one area of data collection from a larger study. The purpose of this study was to explore PSTs' experiences with small-group instruction in a summer mathematics academy focused on the development of number sense in PreKindergarten and Kindergarten students. We crafted the following research question to guide this study: *What are the observed strengths in preservice teachers' small-group instruction in a summer mathematics field experience focused on early number concepts?*

Related Literature

An important aspect of the preparation of PSTs is providing access to a wide range of field experiences. Field experiences can provide many benefits to PSTs, including increasing confidence in teaching mathematics in elementary education majors (Shelton et al., 2020). Jakopovic and Gomez-Johnson (2020) explained that "with limited time to prepare and recruit future teachers, determining the most valuable experiences for students based on content, pedagogy, and understanding of learners is crucial to both formal teacher preparation and supporting programs" (p. 20). However, developing and implementing field experiences can be difficult, as teacher preparation programs must have willing school sites and cooperating teachers to host PSTs for these experiences. Thus, it is important to consider other informal settings that are school-like settings as options for potential field experiences. Informal settings, like a museum, can provide some additional key field experiences for PSTs. Cuenca and Gilbert (2019) documented the benefits that teaching in a museum can provide students and found that "museums can also be used as resources for teacher candidates themselves to develop professional skills, dispositions, and identities" (p. 94). Experiences in these informal, school-like settings provide PSTs additional opportunities to practice the skills of planning and leading instruction.

The field experience we designed for this study allowed PSTs to work with PreKindergarten and Kindergarten students from low SES backgrounds in early number concepts. We selected early number concepts as the focus of the academy based on the research highlighting the importance of early number sense for later mathematical understanding (e.g., Clements & Sarama, 2011; Galindo & Sonnenschein, 2015; Jordan et al., 2009; National Mathematics Advisory Panel, 2008). As a result, we felt that with the importance of early number sense concepts, providing PSTs an opportunity to teach learners in these areas would be a valuable field experience to support their development as future teachers. We include a brief description of the academy in which this experience was situated in the following section.

Description of the Academy

As described in Kerschen et al. (2018), Shelton et al. (2020), and Cooper et al. (2022), the goal of this academy is to develop numerical fluency for students aged 4–6 (grades PreKindergarten and Kindergarten) from low SES backgrounds. The academy is a 4-week experience, 4-days a week, for 3 hours each morning at a museum on the university campus. Each day, the students participate in activities focused on early number concepts in a school-like setting at the museum, which had classroom space. Lead teachers, selected by university teacher education faculty, and local school district leaders coordinate the instructional experiences. Each classroom has a lead teacher from a local school district and teacher assistants who are PSTs taking education courses at the university. The teacher assistants work with the lead teachers to plan and provide small-group instruction. The skills addressed in the academy aligned with the progress monitoring tool, the Texas Early Mathematics Inventory (TEMI; Texas Education Agency/University of Texas System, 2009). The museum setting also offered additional opportunities for students to engage in mathematics-focused activities in the museum.

Methodology

The participants in this study included four PSTs who taught small groups as teacher assistants under the guidance of a lead teacher in the summer before their yearlong internship (student teaching). In conjunction with the academy, we collected data from seven PSTs using interviews, observations of their teaching, written reflections, and a focus group. For these proceedings, we explored the observations of their teaching and included only four of the PSTs in our analysis. We excluded a graduate student serving as a teacher assistant, a PST whose certification was in the middle grades, and a PST who did not participate in all of the study activities. As such, the four PSTs represented in these proceedings represent only the elementary mathematics PSTs who were between their junior and senior year during the time of the academy.

There were two paired observations for each PST using a researcher-developed observation form (see Figure 1). The observation form we used was adapted from the Vaughn Gross Center for Reading and Language Arts (VGC; University of Texas System/Texas Education Agency, 2005) and features effective instruction, given the VGC's mission of improving education outcomes for

Figure 1

Teacher Assistant Observation Form adapted from University of Texas System/Texas Education Agency (2005)

Teacher Assistant Observation Form

TA Name: ________________________ Observer's Name: ________________________ Date: ____________

☐ TEMI Lesson ☐ Station Lesson 3: Highly Effective 2: Effective 1: Somewhat Effective 0: Not effective

The TA….	3	2	1	0
Introduces the concepts and skills in **small steps**.				
Concepts and skills are explained **using clear and direct language.**				
Models and demonstrates procedures with the use of lots of examples.				
Provides **many opportunities for practice** after initial presentation of task/skill.				
Paces instruction adequately by transitioning quickly between tasks and allowing extra time when needed.				
Checks initial practice items for correctness and provides immediate **feedback**.				
Gives **individual and/or group opportunities to respond**. Provides scaffolding to assist students in their learning and practice.				
Monitors students during an activity to be sure that they are performing correctly. Redirects off-task behavior when it occurs.				

Comments/Additional Feedback: (use back if necessary) students from underrepresented populations. The observation form included eight instructional areas. The researchers conducted the first paired observation in the first two weeks of the academy and included a TEMI lesson and a station lesson. They conducted the second paired observation in the last two weeks of the academy. As such, there were a total of four observations of each PST.

Initial Findings

In this section, we focus on the Teacher Assistant Observation Form ratings. Table 1 includes the ratings for each teacher assistant (or PST) and a score representing the change in the TEMI lesson and station lesson ratings over time. We then describe our findings related to the ratings.

In our initial analysis, we observed that the observations of the TEMI lessons showed improvement for three of the four teacher assistants (PSTs). When looking at the individual areas on the observation form, PSTs had the greatest improvement in the instructional area of "Checks initial practice items for correctness and provides immediate feedback" on the TEMI lesson. One observer noted in the second observation of a TEMI lesson, "As students counted the sets, the PST redirected the students struggling with 1:1 correspondence." This is an improvement from the first observation of this PST, in which the observer noted, "When counting, ask them how they see the arrangements." Interestingly, two of the four PSTs received a rating of *highly effective* in all areas of their second TEMI lesson ratings. The PSTs also improved in the area of "Paces instruction adequately by transitioning quickly between tasks and allowing extra time when needed" on both the TEMI lesson and the station lesson. One observer documented that the PST "did a great job not dragging out the warm-up. It was concise, timed, checked, and done."

While overall scores indicate that the station lesson instruction did not improve as it did in the TEMI lessons and revealed a slight decrease for three PSTs, there was some growth in particular areas. For example, in the station lesson delivery, there was some improvement in the instructional areas reflected by "Concepts and skills are explained using clear and direct language" and "Paces instruction adequately by transitioning quickly between tasks and allowing extra time when needed." One observer noted that one of the PSTs who had students with varied learning needs "modified the same tasks to extend for one and help the other."

Table 1

Teacher Assistant Observation Form Ratings and Changes Over Time.

Teacher Assistant Number and Observation Areas	TEMI Lesson 1	Station Lesson 1	TEMI Lesson 2	Station Lesson 2	TEMI Change	Station Change
Teacher Assistant 1						
Small Steps	2	2	2	0	0	-2
Clear Language	2	2	1	2	-1	0
Models	2	2	2	2	0	0
Opportunities for Practice	3	3	2	2	-1	-1
Pacing	1	2	1	3	0	+1
Feedback	2	2	3	2	+1	0
Opportunities to Respond	2	3	3	2	+1	-1
Monitors	1	2	2	1	+1	-1
					Avg. +0.125	Avg. -0.5
Teacher Assistant 2						
Small Steps	3	3	3	2	0	-1
Clear Language	1	2	3	3	+2	+1
Models	3	2	3	2	0	0
Opportunities for Practice	3	3	3	2	0	-1
Pacing	3	3	3	3	0	0
Feedback	1	3	3	1	+2	-2
Opportunities to Respond	3	3	3	2	0	-1
Monitors	1	2	3	2	+2	0
					Avg. +0.75	Avg. -0.5
Teacher Assistant 3						
Small Steps	3	3	3	3	0	0
Clear Language	3	2	3	2	0	0
Models	3	2	3	1	0	-1
Opportunities for Practice	3	3	3	2	0	-1
Pacing	2	2	3	3	+1	+1
Feedback	2	3	3	3	+1	0
Opportunities to Respond	2	3	3	3	+1	0
Monitors	2	3	3	3	+1	0
					Avg. +0.5	Avg. -0.125
Teacher Assistant 4						
Small Steps	0	0	1	0	+1	0
Clear Language	0	0	0	1	0	+1
Models	2	0	0	0	-2	0
Opportunities for Practice	2	1	2	2	0	+1
Pacing	2	1	2	2	0	+1
Feedback	1	1	2	1	+1	0
Opportunities to Respond	1	1	1	1	0	0
Monitors	2	1	0	0	-2	-1
					Avg. -0.25	Avg. +0.25

Discussion and Implications

In this study, we observed strengths by looking at the instructional area ratings and the improvements between the ratings according to the lessons delivered by the PSTs, including the improvement in pacing and feedback. Providing feedback to students is one way to support them in using varied strategies as they engage in productive struggle, and pacing and feedback seem important for monitoring students' progress to promote their learning (National Council of Teachers of Mathematics, 2014).

When discussing the findings, it is important to highlight the differences in the sequencing of this field experience in the PSTs' preparation and the types of lessons observed. This academy occurred the summer before the PSTs' yearlong internship (student teaching). While the PSTs had prior experiences in mathematics classrooms in their junior year, these experiences were limited to seven weeks of planning, designing, and implementing mathematics lessons. Perhaps the structure of this field experience, in which PSTs were able to spend more time with the students in their particular small groups and teach additional mathematics lessons for four weeks, supported their development of providing feedback and developing appropriate pacing. In our exploration of the data, we observed differences in the ratings between the two lesson types taught by the PSTs. While this was not something we set out to study, the results suggest that the type of lesson may have played a role in the ratings. The TEMI lessons were based on a scripted curriculum, while the PSTs developed and planned the station lessons. That might be a contributing factor in the differences observed between their scripted TEMI lessons and non-scripted station lessons. It appears that the PSTs became more comfortable with the scripted aspects of the curriculum as the academy progressed. As they gained experience with the curriculum throughout the academy, they were able to improve on specific instructional areas highlighted in the observation form. Lower scores on these observations may suggest that PSTs needed additional time and experience designing specific learning experiences for their students. The additional demands of planning and implementing a specific station lesson may be one of the reasons explaining the lower observation ratings. We plan to explore this observation more in-depth in a future study.

These findings have several implications for the future of this summer field experience and the academy. In future iterations of the academy, it might be beneficial to target the lower-rated areas of the observation form during pre-academy training for the PSTs. It might be helpful to discuss the observation form with the PSTs, highlighting specific examples of best practices in each of the areas on the form. Based on the observations of the differences between the ratings of the lessons, it might be beneficial for PSTs to have scripted lessons for both the TEMI and the stations at the beginning of the academy. This may help them develop familiarity with the curriculum for both lessons early on which may lead to an improvement in the instructional areas highlighted on the form. Because PSTs had not yet completed their internship, scaffolding the expectations for them in this experience may help address some of the missed opportunities noted in their station lessons. Our intent is that having the opportunity to teach both scripted and unscripted lessons in the summer before their internship will help better prepare them for that experience. Also, the observers in this study did not have the opportunity to debrief with the PSTs after the completed observations. In the future, providing opportunities for this debriefing may assist with the development of the PSTs in implementing their instruction in these small groups.

It is important to note that these proceedings focus on one data source (observations) that we collected from four PSTs. We intend to continue our exploration by incorporating the data from other data sources, including interviews and focus groups.

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ENHANCING STUDENTS' UNDERSTANDING THROUGH THE USE OF MULTIPLE SOLUTION STRATEGIES

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Abstract

This study investigates the impact of multiple solution strategies on students' conceptual understanding of whole number multiplications and divisions in developmental mathematics, analyzes their conceptual knowledge using the Lesh Translation Model, and identifies preferred strategies. Additionally, the focus group interview assesses students' perceptions and learning experiences related to these strategies. The findings demonstrate a positive influence of multiple solution strategies on students' developmental mathematics learning. The most used strategies were the Lattice method, German method, and the Standard algorithm. Participants believed using different methods would facilitate their understanding of the concepts and enhance their fundamental mathematics learning experience.

Keywords: Multiple Solution Strategies, Conceptual Understanding, Developmental Mathematics

Introduction

Although students' enrollment in STEM disciplines has dramatically increased, their graduation rate remains relatively stagnant due to low retention rates (Thompson & Bolin, 2011). This can be partially attributed to the challenges posed by developmental mathematics, which has been identified as a significant obstacle (Zhao et al., 2018). For college entrants, up to 60% necessitate a developmental mathematics course or lack preparedness for the required mathematics courses in their majors (Radford et al., 2012). There is a need for supportive techniques, especially instructional methods, to enhance the success of developmental mathematics students (Fay, 2020). Research recommends implementing multiple solutions to promote conceptual understanding across all grade levels, positively impacting algebraic problem-solving (Lim et al., 2015; Tsamir et al., 2010). However, limited research exists on how multiple solution strategies foster students' conceptual understanding in developmental mathematics.

Objectives of the Study

This study aims to investigate the effect of using multiple solution strategies on students' understanding of whole number multiplications and divisions and examine their perceptions and experiences regarding these strategies. The specific research questions are: 1) Is there a significant difference in the number of strategies used for whole number multiplications and divisions between experimental and control groups? 2) How do students in the experimental and control groups differ in their conceptual understanding using the Lesh Translation Model? Which strategies are most used by students? 3) What are students' perceptions and experiences of using multiple solution strategies?

Related Literature

Multiple Solution Strategies

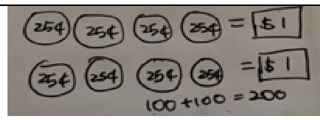
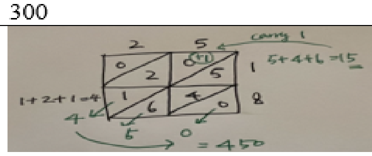
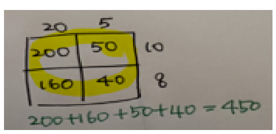
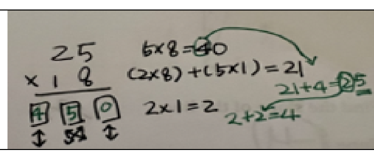
Multiple solution strategies are a pedagogical method that employs various approaches to solve mathematical problems (Groβe, 2014). Students who compare strategies have greater procedural flexibility and procedural and conceptual knowledge than students who study examples sequentially (Star et al., 2016). Rittle-Johnson and Star (2007) found that employing multiple solution methods for solving a single problem led to better student conceptual and procedural knowledge performance than using only one approach at a time. Groβe and Renkl's (2006) study revealed that using multiple solution methods assisted students in applying methods more effectively and developing problem-solving skills. When teachers show multiple solutions to a problem, the quality of the lessons is enhanced (e.g., Große, 2014; Tsamiret et al., 2010). Große (2014) found that multiple solution methods can encompass various representational formats (i.e., calculations, tables, and graphics), assisting students in preventing misinterpretations and enhancing a deeper understanding of mathematical concepts. Specifically, multiple strategies have positively impacted problem-solving abilities in Pre-Algebra and Algebra (Lim et al., 2015). Figure 1 presents examples of student multiple solution strategies for this study. Despite its importance, the use of multiple solution strategies is underexplored in developmental mathematics, especially for those pursuing careers in STEM education. Given the significance, assessing students' conceptual understanding becomes crucial. For this purpose, the Lesh Translation Model is used as a robust framework.

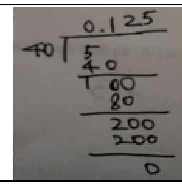
Lesh Translation Model (LTM)

The Lesh Translation Model (LTM) offers a framework to assess students' conceptual understanding by translating knowledge among various representations (Lesh & Doerr, 2003; Moore et al., 2013). It focuses on five modes: *realistic* (real-world experiences or metaphors), *symbolic* (Standard algorithm), *language* (spoken or written), *pictorial*, and *concrete* (math manipulatives). Connecting these representations deepens conceptual understanding. Figure 2 demonstrates how students transfer mathematical ideas between representations through straight arrows and transition within the same mode through curved arrows (Joung et al., 2021).

Figure 1

Examples of student multiple solution strategies

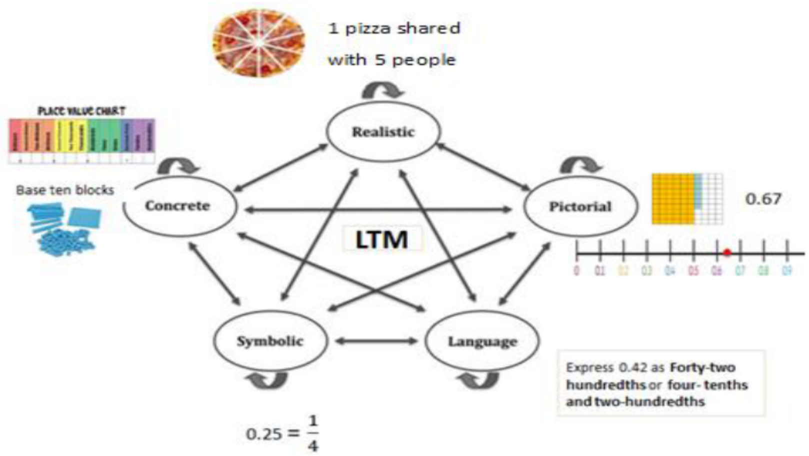
Multiplication Strategies	Student Example
Standard Algorithm 25 × 8 25 × 18	25 × 8 200 25 × 18 200 250 450
Repeated addition 25 × 8	25+25+25+25+25+25+25+ 25 = 200
Pictorial representation 25 × 8	
Decomposition 25 × 6 25 × 12	(20 × 6) + (5 × 6) =120 + 30 = 150 (25 × 6) + (25 × 6) = 150 + 150 = 300
Lattice method 25 × 18	
German method 25 × 18	
Vedic method 25 × 18	
Using factors 25 × 6	5 × 5 ×3 × 2 = 25; 25 × 6 = 150

Division strategies	Student Example
Standard Algorithm 5÷ 40	
Using multiplication 5 ÷ 40	5 × **8** = 40
Pictorial representation (8 groups of 5 tallies) 40 ÷ 5	There are eight groups, totaling to "40". ||||| ||||| ||||| ||||| ||||| ||||| ||||| |||||
Fraction 40 ÷ 5 5÷40 (%)	40/5=8 5/1 ÷ 40/1 = 1/8
Chunking 25 ÷ 5	Students divided the dividend (25) into equal groups of the divisor (5) until they had used up all the dividend.
Division by repeated subtraction 40÷5	40-5=35, 35-5=30, 30-5=25, 25–5= 20, 20-5=15, 15-5= 10, 10-5=5, 5-5=0 (subtracted 5 8 times)
Equation 5 ÷ 40	40 × x = 5, x = 5/40 =1/8= 0.125

In line with the LTM framework, it is considered that students who can translate their solutions *between* or *within* at least two different representations as demonstrating conceptual understanding. Applying LTM's representations to understand multiplication and division plays a critical role in building students' foundational mathematics skills. In this regard, the LTM representations are crucial for analyzing our study's results as they reflect not only procedural skill but also a deeper understanding of mathematical concepts, particularly division. Consequently, integrating the LTM into instruction and incorporating multiple representations holds tremendous potential for improving students' conceptual understanding and promoting effective learning outcomes (Lesh & Doerr, 2003).

Figure 2

Example of Lesh Translation Model representation (Joung et al., 2021, p.70)



Methodology

A pretest-posttest quasi-experimental design was used, and mixed methods research was applied to gather more profound insight into students' understanding of multiple solution strategies.

Participants

A total of sixty-three undergraduate students enrolled in a developmental mathematics course, Beginning Algebra, participated in this research study. Among these students, the experimental group (n=26) received instruction using multiple strategies, while the control group (n=37) underwent traditional instruction. These students were pursuing careers in STEM education.

Instruments

Students solved four whole-number multiplication and division problems using multiple strategies. These problems included two-digit by one-digit multiplication (e.g., problem 1 - pretest: 25×8; posttest: 25×6), two-digit by two-digit multiplication (e.g., problem 2 - pretest: 25×18; posttest: 25×12), two-digit division by one-digit (e.g., problem 3 - pretest: $25 \div 5$; posttest: $40 \div 5$), and one-digit division by two-digit (e.g., problem 4 - pretest: $5 \div 25$; posttest: $5 \div 40$). These specific problem sets were chosen to increase complexity gradually, cater to diverse learning styles, and enhance student motivation and engagement. The pre-and post-test formats are used as valuable formative assessments. For research question 3, a focus group (n=10) was voluntarily selected to gain a deeper understanding of the results and to build construct validity. The interview questions were then provided: 1) Can you describe how multiple-strategy instruction impacted your learning experience? 2) Can you share your preferred strategy for solving whole number multiplication or division problems? 3) What challenges did you face while learning multiple strategies?

Procedures

The experimental group completed a pretest before undergoing an intervention with multiple solution strategies. They then took a posttest. During the intervention, the instructor introduced multiple solution strategies while teaching fundamental math concepts related to whole numbers, rational numbers, and algebra throughout the semester. Multiplication and division of whole numbers were selected as a basis of the critical areas for students to apply their understanding of these multiple solution strategies. Meanwhile, the control group completed a pretest before receiving traditional instruction without such strategies; they then took a posttest. To gain further insights into their experiences with multiple solution strategies in developmental mathematics, focus-group interviews were conducted in the experimental group.

Data Analysis

The Mann-Whitney U test was employed due to the unequal sample size to determine if there is a significant difference in students' performance on whole number multiplications and divisions between the experimental and control groups. Implementing multiple experimental and control strategies was analyzed using the LTM. The focus group interview summarized students' experiences with multiple solution strategies.

Results and Discussion

Performance Comparisons between Control and Experimental Group

To respond to the first research question, the Independent-Samples Mann-Whitney U Test was conducted to compare the median number of strategies due to the unequal number of participants. As shown in Table 1, there were no significant differences observed among problem 1 ($U=439.00$, $p=.529$), problem 3 ($U=367.00$, $p=.092$), and problem 4 ($U=453.50$, $p=.684$) between the two groups. However, problem 2 (e.g., pretest 25×18; posttest 25×12) exhibited a significant difference ($U=324.50$, $p=.018$). The experimental group showed a significantly larger median ($Mdn = 38.02$) than the control group's median ($Mdn = 27.77$). This finding suggests that the number of multiple solution strategies for the experimental group in multiplying a two-digit whole number by a two-digit number significantly differed from the control group.

Table 1

The Results of the Independent-Samples Mann-Whitney U Test

Variable	Mean Rank		U	z	p
	Control (n=37)	Experimental (n=26)			
Problem 1	33.14	30.08	439.00	-.63	.529
Problem 2	27.77	38.02	324.50	-2.37	.018
Problem 3	35.08	27.62	367.00	-1.69	.092
Problem 4	32.74	30.94	453.50	-.41	.684

Comparison of Students' Conceptual Knowledge and Strategies They Use

To address research question 2, we compared the multiple solution strategies used by the experimental and control groups to analyze students' conceptual understanding of multiplication and division. Conceptual knowledge was demonstrated by students' ability to translate within and between LTM representation modes. Figure 3 illustrates the percentage of students proficient in translating within or between more than two LTM modes using multiple solution strategies. Both groups showed high percentages of students using multiple strategies to correctly solve the four problems. In particular, in the 5÷40 problem, the experimental group had a significantly higher percentage of participants (50%) than the control group (32%). These results highlight the benefits of implementing multiple solution strategies in enhancing students' conceptual understanding, particularly when tackling more complex problems (e.g., 25 × 12 and 5 ÷ 40). The findings suggest that experimental group participants demonstrate their ability to make connections between division and fractions.

Figure 3

Percentage of Students Showing Conceptual Understanding by Translating within or between LTM Modes

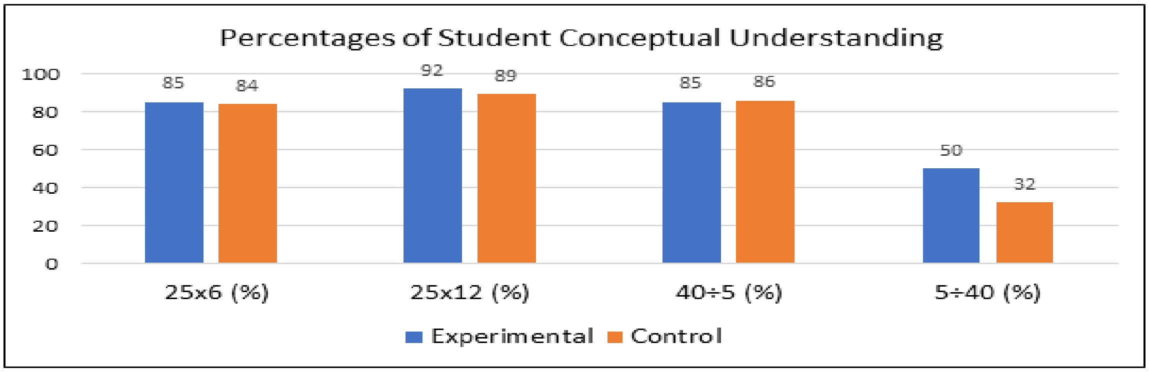


Figure 4 compares the types of multiple solution strategies the experimental and control groups used for correctly solving multiplication problems. The *Standard algorithm* was most common, with the experimental group displaying greater diversity in multiple solution strategies like *Repeated addition*, *Lattice method*, and *German method*. Students correctly solved the given problems using the *Lattice method* for the more complex multiplication problem (25 × 12: 14%), compared to the simpler one (25 × 6: 9%). This indicates that students achieved higher accuracy or success in solving more complex problems using the *Lattice method*. Additionally, the experimental group found more correct answers using *Pictorial representation* and *Decomposition*.

Figure 4

A Comparison of Different Strategies on Whole Number Multiplication

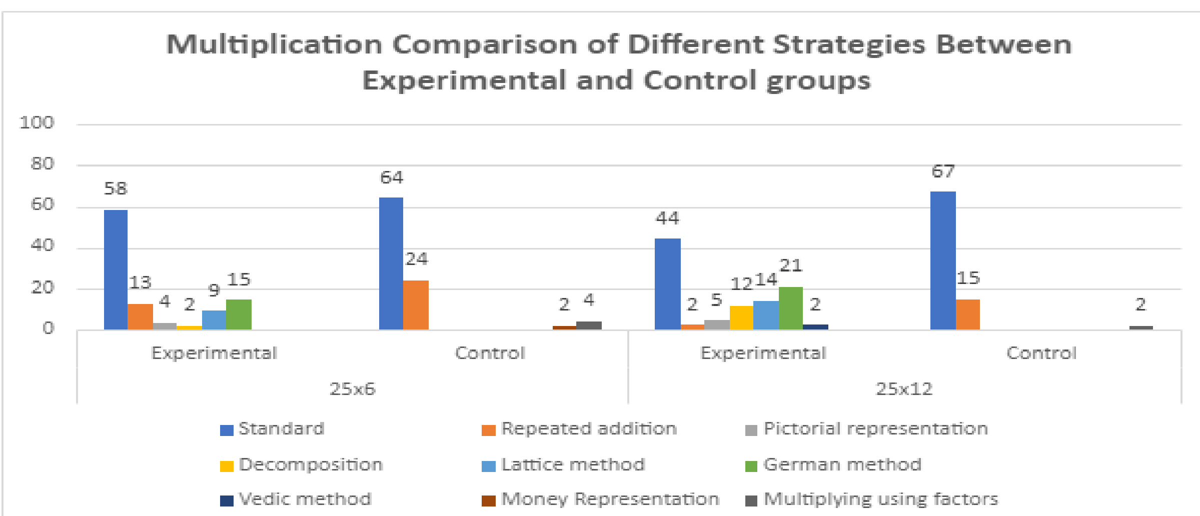
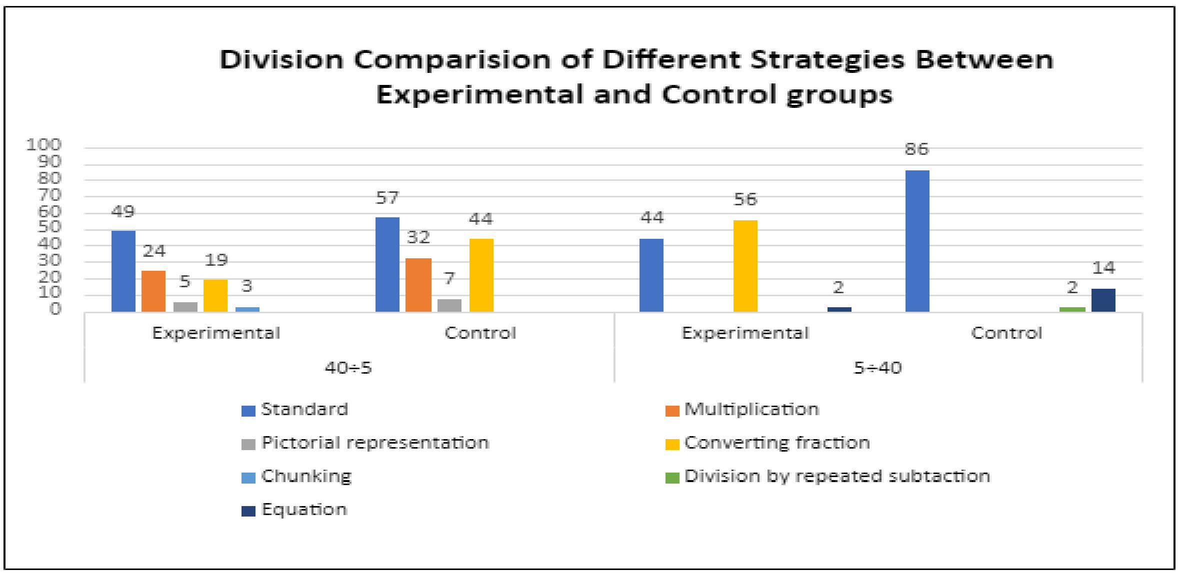


Figure 5 compares the percentage of students in the experimental and control groups who used each type of division strategy. In the 40 ÷ 5 division problem, the *Standard algorithm* was most prevalent for both groups. Both groups also used *Multiplication* (i.e., 5×8 =40), *Pictorial representations*, and *Converting fractions* (i.e., 40/5). However, *Chunking* was used minimally in the experimental group as well. There was a noticeable shift for the 5 ÷ 40 problem. The experimental group now preferred *Converting fractions* while still using the *Standard Algorithm* The control's groups preference for the *Standard Algorithm* increased dramatically, with a few control students now using *Division by repeated subtraction* and *Equations(i.e.,40x=5)* Notably, unlike the experimental group, no control students used *Converting fractions*. No students in either group used *Multiplication*, *Pictorial representations*, or *Chunking*. Overall, in both problems, the *Standard Algorithm* was the primary strategy with other strategies like *Multiplication*, *Pictorial representations*, *Chunking, Equations,* and *Division by Repeated Subtraction* being used but only minimally.

Figure 5

A comparison of different strategies on whole number divisions



Students' Perceptions and Learning Experience of Multiple Strategies

To address research question 3, students' perceptions and experiences of multiple strategies were summarized through the focus group interview.

Impact of multiple strategy instruction. Students provided positive feedback about multiple solution strategy instruction. For example, three participants reported that learning various problem-solving methods was enjoyable and a positive experience. Two said that benefits included expanded thinking. Other benefits mentioned were increased confidence in mathematics, increased effectiveness in solving different problems, appreciation for learning new methods, increased opportunity to choose a preferred strategy, and envisioning problems differently (one for each).

Preferred strategy. The most preferred strategy was the *Lattice method* (3 students) because it was easy to use once they understood the concept inside and allowed them to break down larger math problems best. The *German method* and *Standard algorithm* followed closely behind (2 students, respectively). One student mentioned finding the *German method* easier to split multi-digit numbers into simpler ones, and it helped her keep her mathematical work organized and neatly arranged on the page, leading to better comprehension and clarity during problem-solving. Also, two students stated that the *Standard algorithm* remained convenient because they had learned it during their school days and had stuck to this method for a long time. In summary, this study found that students enjoy learning whole number multiplications and divisions using the *Lattice* and *German* methods. Past research has shown that proficiency in multiplication can enhance performance in division, which makes sense as multiplication is often used to check division work (LeFevre & Morris, 1999). By incorporating these popular strategies into instruction, teachers may help improve student performance in the division.

Challenges faced while learning multiple strategies. Two participants mentioned difficulties in comprehending specific strategies, but they successfully overcame these difficulties through questioning and practice. Another student felt challenged by the need to step out of their comfort zone when learning new methods. Additionally, one student struggled with remembering and mixing up different approaches while finding some strategies unnecessarily complex for specific problems. Moreover, another student had difficulty applying the new methods during tests and relied on familiar approaches. However, most students did not encounter any challenges and found it easy to learn and use multiple strategies.

Implications

This analysis enables educators to identify effective teaching approaches while emphasizing the importance of diverse strategies to accommodate individual learning needs. The preferred *Lattice method* stands out for its simplicity and organizational benefits. Implementing multiple solution strategies positively impacts student experiences, allowing them to discover preferred techniques, adapt to various problem types, and gain new perspectives. Teaching multiple strategies better engages and supports students in learning fundamental mathematics, and comparing strategies helps identify learning gaps requiring reinforcement. The experimental group's effective use of multiple solutions in multiplication problems improved results and enhanced conceptual understanding.

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