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Fostering Student Beliefs About Engineering and Mathematics Through Integrated Instruction (RTP)

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Abstract

Third through fifth grade is where students begin to develop their STEM identities to connect their education and the real world. Prior studies of integrated STEM teaching at the middle school level improved students' mathematics self-efficacy and perceived mathematics usefulness. The purpose of this study was to understand how an integrated teaching model (e.g., science, engineering, and mathematics) influenced 5th-grade students' perceptions of their mathematics and engineering abilities. We sought to answer the following research question using a sequential mixed methods research design: how do 5th-grade students' mathematics and engineering self-efficacy and instrumentality for abstract mathematics concepts change because of an integrated teaching experience?

We utilized self-efficacy [1] and perceived usefulness [2] frameworks to explore how students develop their perceived abilities and usefulness of mathematics through integrated instruction. Seventeen students from a Title-I elementary school worked in teams to design solutions that could provide residents access to clean water. During the integrated unit, students took a pre-, mid-, and post-survey. The items on the survey came from four pre-existing surveys: (1) The Patterns of Adaptive Learning Survey [3], (2) Mathematical Attitude Assessment [4], (3) Engineering Skills Self-Efficacy Scale [5], and (4) Intersectionality of Non-normative Identities in the Cultures of Engineering Survey [6]. The post-interviews captured students' perceptions of their motivations regarding engineering and mathematics.

The quantitative and qualitative data created a holistic understanding of how students' perceptions of their abilities shifted throughout the integrated unit. Quantitative data indicated a decrease in self-efficacy but an improvement in perceived mathematics usefulness from mid-unit to post-unit. Qualitative data indicated an increase in students' confidence to do difficult math at the end of the unit. Together results indicated that integrated teaching approaches could foster positive shifts in students' perceived STEM abilities. This kind of instruction could allow students to use and build a broader range of perceived STEM abilities to solve a problem.

Introduction and Literature Review

As students transition from elementary to middle school, there is a decline in students' beliefs about their mathematics ability [7]. Students perceive mathematics as something "they can do" or "they can't do" because of difficulties related to the abstraction of the academic content [8]. This perception can cause students to question the relevance of the content they are learning inside and outside the academic content area. Establishing students' positive self-beliefs about their academic capabilities early on is vital as their beliefs about their abilities become less malleable over time [9]. If students do not understand mathematics and do not believe they can do it, they become disinterested and ultimately abandon pursuing mathematics and mathematics-related fields such as engineering [10].

The integration of engineering with math and science is one mechanism that can foster the adoption of positive beliefs about mathematics. Harlan et al.'s [11] longitudinal comparison study of middle school student cohorts showed the combination of engineering and mathematics had positive effects on students' mathematics self-efficacy and development of mathematics skills. The context of engineering can offer a framework that makes the perceived usefulness of mathematics explicit and immediate. In Chiu et al.'s [12] study, 7th-grade students attending schools designated by their representative states as "low-performing" were taught mathematics using WISEngineering, a web-based engineering design learning environment that integrates mathematics concepts [12]. The WISEngineering units were replacement curricula for the standard mathematics curricula. Students developed understanding and competence in crucial mathematics concepts such as spatial reasoning and improved their mathematics attitudes [12]. Similarly, 6th through 8th grade students enrolled in a middle school engineering class transferred their science and math knowledge from their engineering class to their science and math classes [13]. These students also showed increased academic self-efficacy in the areas of math and science [13]. Given the positive results at the middle school level (e.g., [11]–[13]) and limited work at the elementary level, we wondered what impact engineering, mathematics, and science integration could have. We focused on mathematics self-efficacy in 5th-grade since the elementary to middle school transition is a formative time in terms of students' perceptions of their capacity to do mathematics. We conducted an exploratory study to investigate this, drawing on Bandura's [1] conception of self-efficacy, and Kirn and Benson's [14] work focused on perceived usefulness.

Theoretical Framework

We utilized two framings of students' beliefs to examine how engineering can foster 5th grade students' beliefs concerning their mathematical abilities: self-efficacy and perceived usefulness. Self-efficacy describes a person's beliefs, thoughts, and judgments developed by engaging in learning and performance [1]. According to Bandura [1], an individual's self-efficacy is shaped in the following four ways: (1) the person's success while performing the task, (2) an individual's perception of peers' success during the task, (3) the verbal feedback received as one engages in the task, and (4) the negative and positive feelings that occur as the individual performs the task. Further, self-efficacy has been consistently connected to educational outcomes in mathematics and engineering education, including but not limited to performance ([15]–[17]), student development of design skills [18], and seeing oneself as an engineer[19].

Perceived usefulness is defined as the value of tasks for the future and is similar to utility value and instrumentality in the motivation literature [2]. Like self-efficacy, perceived usefulness has been connected to several educational outcomes. These include increased task persistence, deep learning, and increased valuing of present tasks [14]. Perceived usefulness is defined as the value of tasks for the future and is similar to utility value and instrumentality in the motivation literature [2]. Both of the frameworks in this study measure different aspects of students' beliefs about their abilities in math and engineering and are utilized as they can shift due to educational experiences [20], [21]. The operationalization of these constructs, along with our population and study design, are outlined below.

Research Question

By building off the body of available literature about student mathematics and the role of engineering in fostering positive beliefs, we sought to implement an integrated engineering, science, and mathematics unit and answer the following research question:

How do 5th-grade students' mathematics and engineering self-efficacy and perceived usefulness for abstract mathematics concepts change following participation in an integrated learning experience?

Below we describe the intervention, the integrated math, science, and engineering unit, followed by discussing our research methods. Finally, we conclude by examining our findings within the context of the literature.

Integrated Math, Science, and Engineering Unit

The engineering design process anchored mathematics and science learning throughout our integrated unit. Students engaged in lessons to explore science, engineering, and mathematics interconnections and designed solutions for a water quality problem. Table 1 provides an overview of the key topics addressed in the unit. Appendix A displays a lesson plan used to teach a key topic, conservation of mass and operations and algebraic thinking. The first six weeks of the unit were teacher-led guided instruction of mathematics concepts, science concepts, and engineering concepts. The teacher and first author was an experienced upper-elementary special education teacher with training in science and mathematics education and a degree in teaching students with moderate to severe learning and behavioral disabilities. At the time of this study, she was working on her Master's in STEM Education.

At the outset of the unit, students developed knowledge on different forms of water quality issues. The unit introduced students to the client, a small community in the state that needed an affordable water filter because of a contaminated water supply. Each lesson concluded with a discussion that provided students with a summary of the content knowledge learned during the lesson. Before, during, or immediately following each lesson, the teacher asked students to consider the ways the content related to the engineering design process.

The last six weeks were student-led and featured opportunities to apply acquired mathematics, science, and engineering concepts in groups and plan and build a working prototype. The seven student teams were composed of three to four students each. The teams were randomly assigned to encourage heterogeneity of the teams and were not based on gender, ability, or other criteria. At the end of the unit, a showcase of prototypes included the student teams presenting their prototypes to the executive director of an Environmental Engineering firm, engineers from the local university, and an engineer from a Major Automotive Manufacturer for evaluation.

Table 1: Overview of the Key Topics in the Integrated Mathematics Unit

Week	Engineering Design Process	Science Topics	Mathematics Topics
1-2	Identification of problem and scenario Researching current water filtration devices	Separation of a mixture and a solution Determining the mass of a mixture and solution	Writing numerical expression with math symbols and words for mixture/solution Writing a numerical expression with math symbols and words for the mass of mixture/solution
3	Students drawing their own filtration devices	Determining the concentration of a solution	
4	Providing labels and measurements for filtration devices	Determining saturation of a solution	Writing numerical expression for saturation
5-6	Students give feedback and receive feedback from peers on their drawings	Materials that filter out bacteria	
7-8	Students design and evaluate their filtration devices		Deriving flow rate ratio for selected materials in the filtration device
9-10	Students evaluate their filtration devices		Data collection and interpretation
11	Students present prototypes to a business member and local engineers		

Multiple resources support the coherence of content knowledge and pedagogical teaching strategies required of engineering, mathematics, and science. The mathematics resources used were the 6th grade Engage New York mathematics module Expressions and Equations [22] and the Ratios and Proportional Relationships [23], and the grade 5 module Operations and Algebraic Thinking [24]. The science resource used was the grade 5 FOSS Next Generation Mixtures and Solutions [25], and the engineering resource used was Design It Clean: The Water Filter Challenge. Each resource used aligned with K-12 national standards for the subject area.

Research Methodology

The purpose of this exploratory sequential mixed-methods study was to understand students' mathematics and engineering self-efficacy during integrated engineering, science, and mathematics lessons. Additionally, the study sought to examine students' perceived usefulness for mathematics through the integrated unit. We used sequential data collection to measure the development of mathematics and engineering self-efficacy and perceived usefulness of mathematics. Collection of quantitative data occurred before, during, and after the intervention, along with qualitative data collected after the intervention. The quantitative data explored students' mathematics self-efficacy and perceived usefulness of mathematics. The qualitative data provided a more detailed explanation of the students' perceptions of their mathematics self-efficacy and perceived usefulness of mathematics during the integrated learning experience [26].

Context and Student Participants

The study was conducted in a northern Nevada Title I elementary school during the 2017-2018 school year. The school's racial/ethnic demographics were 35% Caucasian, 57% Hispanic, 4% Multiracial, 2% English Language Learners', and 26 % had Individual Education Plans. The class demographics for participating students in the study were 54% female students and 46% male students. Additionally, 38% were Caucasian, 54% Hispanic, and 8% categorized as Multiracial. Lastly, 35% were English Language Learners, and 8% had an Individual Education Plan. The 17 student participants received parental consent for the research and assented to research participation. The teachers did not exclude students from participating in the integrated engineering, mathematics, and science unit. The Institutional Review Board at the second author's institution approved all study procedures.

Quantitative Data Collection and Analysis

Engineering Self-Efficacy (ESE) and Mathematics Self-Efficacy Survey

The first and second authors created an eleven-item survey for use in this study. The authors adapted items in this survey from four pre-existing surveys: (1) The Patterns of Adaptive Learning Survey [3], (2) Mathematical Attitude Assessment [4] (3) Engineering Skills Self-Efficacy Scale [5], and (4) Intersectionality of Non-normative Identities in the Cultures of Engineering Survey [6]. Our survey items measured the constructs of engineering and academic self-efficacy and perceived usefulness. Sample items: engineering self-efficacy ("I can evaluate a design."), academic self-efficacy ("Even if the work is hard, I can learn it.") and perceived usefulness ("I do not understand why I need to study math."). The researchers of these existing surveys used content, construct, predictive, convergent, and criterion to ensure validity. Given our limitations with sample size, additional reliability and validity testing was not feasible during this study and should be the focus of future work. Still, the robust evidence supporting the survey items allowed us to move forward with this preliminary exploratory study.

The adapted items in our survey fell into three categories: (1) mathematics self-efficacy, (2) perceived usefulness of mathematics, and (3) engineering self-efficacy. These items and their associated categories are described in Table 2. Modifications were made to the wording of items to help with student comprehension and match the study's content — mathematics and engineering self-efficacy. Also, two 5th-grade teachers at the study site reviewed the survey before distribution to make sure it was at or below a 5th-grade reading level. A 5-point Likert-type scale was utilized in the survey ranging from 0 (strongly disagree) to 4 (strongly agree). The authors summed item scores by category for analysis, described below. For example, a student could have a maximum score of 12 of their math self-efficacy score.

Table 2: 'ESE and Mathematics' Survey Questions and Associated Categories

Category	Items
Math Self-efficacy	1. I am confident I can learn math that is taught in class. 2. I can figure out how to do most of the difficult math in this class. 3. Even if math is hard, I can learn it.
Perceived Usefulness	1. What I learn in this class will be important for my future classes. 2. I see how difficult math is used outside of school. 3. The math I learn in school is not important to my life. 4. I do not understand why I need to study math.
Engineering Self-efficacy	1. I can use math to design a solution for an engineering problem. 2. I can use math to make a model of my engineering design. 3. I know how to test the engineering model I design using math. 4. I know how to judge how well my model works using math.

Survey Administration and Data Collection

The students were administered the survey three times during the twelve-week integrated math lessons. The pre-survey was distributed in September 2017 during the start of the school year. The first survey was administered six weeks after the September 2017 pre-survey, and the second survey was administered six weeks from the first survey. The survey was read aloud each time to the students to reduce the impact of the students' reading abilities limiting survey responses. After the unit, each student was interviewed one-on-one.

Results

A Friedman rank-sum test [27] was conducted on the 17 students' summed survey responses. This non-parametric test is used to detect distributional differences in a single group over time. This test shows the aggregate total of items that compose each of the three survey categories: *mathematics self-efficacy, perceived usefulness of math,* and *engineering self-efficacy* on the ESE and Mathematics Survey. The outcomes presented in Table 3 are for the pre, mid, and post data for the ESE and Mathematics Survey based on the 5-point Likert type scale ranging from 0 (strongly disagree) to 4 (strongly agree). Data reported include survey categories, means of summed scores for each time point with (standard deviation), chi-squared, degrees of freedom, and p-values.

Table 3: Friedman Rank-Sum Analysis of the ESE and Mathematics Survey Responses.

Survey Category	M_{pre} (SD)	M_{mid} (SD)	M_{post} (SD)	χ^2	df	p
Mathematics Self-Efficacy	9.12 (2.37)	9.12 (2.29)	7.82 (2.86)	7.58	2	0.02*

Perceived Usefulness of Math	13.00 (2.71)	11.71 (3.37)	14.00 (1.58)	4.51	2	0.11
Engineering Self-Efficacy	12.69 (7.07)	11.18 (2.94)	11.88 (3.10)	1.82	2	0.40

* significant at $p \leq 0.05$

Results indicated a statistically significant change in students' mathematics self-efficacy scores, with the lowest mean score occurring for the post-survey. A post hoc Nemenyi multiple comparison test was conducted for each survey category to identify where differences occurred. Table 4 shows the results of the post hoc Nemenyi tests for each of the three survey categories: Mathematics Self-Efficacy (MSE), Perceived Usefulness of Mathematics (MPU), and Engineering Self-Efficacy (ESE).

Table 4: Post Hoc Nemenyi Tests of the ESE and Mathematics Survey Responses

Variable	p_{MSE}	p_{MPU}	p_{ESE}
Pre-Mid	0.86	0.31	1.00
Mid-Post	0.17	0.08	0.56
Pre-Post	0.05*	0.77	0.56

* significant at $p \leq 0.05$

First, this post hoc analysis confirmed that the difference in MSE mean scores from pre to post is statistically significant at the $\alpha = 0.05$ level. Secondly, while not statistically significant at the $\alpha = 0.05$ level, this analysis revealed a noteworthy change in MPU mean scores from mid to post. Lastly, this analysis confirms no statistically significant differences between the pre, mid, and post mean scores for the engineering self-efficacy category.

Together, these quantitative results suggest that participating in mathematics and engineering integrated teaching experience led to a significant *decrease* in students' mathematics self-efficacy, which is at odds with the current understanding of this relationship in middle school students (e.g., [11]–[13]). However, the broad self-efficacy literature notes that self-efficacy is situational and can increase, remain stable, or decline during a task as one understands the skills needed to complete a task [1]. It is not surprising that students' participation in their first engineering design experience would feel less efficacious after completing the unit. Our analysis of the qualitative results below will explore these patterns and trends to understand how students internalized their experiences during the unit.

Qualitative Data Collection and Analysis

Student Interviews

The first author interviewed all students in the class and sent interview transcripts to an external researcher who removed data for those without consent and assent. Students were given a unique number for their interviews and matched with quantitative data by the external researcher. The individual interview sessions with the students sought to explain the quantitative results by highlighting students' experiences related to their mathematics and engineering self-efficacy and perceived usefulness of mathematics.

Students' interviews occurred within three days after completing the unit to ensure students could recall their thoughts and feelings about their experiences. The first author read speech-to-text transcripts of the interviews to the students to minimize inaccuracies and correct transcription errors. These two methods helped to ensure elements of interpretive validity [28]. To ensure the content validity of the interview questions, two researchers from the second author's research team developed the initial questions for the interviews based on their extensive K-12 experiences. The question development was guided by the definition of each category within the eleven-item survey to create questions focused on mathematics and engineering self-efficacy. The questions were discussed and modified with the second author, who has expertise in the frameworks used in this study [21]. The interview was semi-structured and included questions such as: what parts of the unit made you feel confident about your math ability? What do you think about learning math with engineering? The semi-structured interview protocol and open-ended questions are found in Appendix B.

Coding and Analysis

The first author analyzed the interview data in three rounds with oversight from the second author. The first round of coding was for preliminary phrases that were coded and sorted into categories. If a student mentioned something similar to "doing math with engineering is easy, but I thought it's going to be hard"; this was coded as self-efficacy. In the second round of analysis, we looked across codes for similarities and differences in student responses. We collapsed similar codes, which eventually became the initial themes for the category. After another round of analyzing the codes and initial themes for similarities or differences, final themes were generated [29]. The two themes derived for perceived usefulness are "the importance of math for their futures" and "the application of math to daily life." The two themes constructed for mathematics self-efficacy are "variability in students' self-efficacy based on previous experiences in math" and "integration was a value-added experience for students." The data suggest the students' development of perceived usefulness of mathematics and mathematics and engineering self-efficacy resulted from events that occurred during the unit. As we present the data below, brackets have been placed within quotes to clarify the students' statements, and all names are pseudonyms.

Perceived usefulness

Collectively, interview responses indicated that students saw mathematics as useful for their lives now and in the future. For example, they recognized mathematics as important for their future schooling, including describing mathematics related to middle school, high school, and college. Finally, students viewed mathematics as important for developing their math abilities and usefulness in their everyday lives.

Theme: Importance of math for their futures. The students believed the mathematics they learned in the integrated unit would be important for future grade levels. "[The engineering math] will help me with my math in sixth grade and middle school," stated Zy. Brandon focused on high school and college. He said, "I may use [the] difficult math in high school and college." Kara not only focused on school but also on future employment, "[The engineering math] helps you in higher grades or [if you] want to get a job you're going to need [it]." Based on these comments, the integrated unit appeared to help students construct a positive conceptual view of abstract mathematics concepts they will learn and apply in future grade levels.

Theme: Application of math to daily life. The students' participation in the unit helped them connect the usefulness of mathematics to their own lives. This result emerged from students expressing improved abilities with activities that required math in their daily lives. When responding to the question, "After using math and engineering together, has your view of math changed?" Jessy said, "Buying stuff [with] money because now I can give [the correct] money [at] the register and divide things equally." Zy discussed his self-perceived improvement in his tinkering abilities. He said, "[The difficult math] will help me with fixing things outside of school." Along these lines, this increased confidence led students, such as Kara, to express the usefulness of math in activities outside of school: "[The] engineering math [can help] outside like on my house, if my mom and dad give me engineering math or something like engineering for science math I could do most of it." When examining this theme, students' demonstrated that their increased self-efficacies helped foster their perceptions of math from different STEM domains as useful outside of the classroom. The differentiation of math in different STEM domains was derived from participant language and was not an artifact of instruction. These findings did not explore the definitions students had for each of these domains, and should be the focus of future work.

Mathematics Self-Efficacy

When students were asked about their mathematics confidence, they drew on their past math experiences to describe shifts towards more positive self-efficacy conceptions. Similarly, the students described experiences that highlighted how challenging, integrated tasks resulted in those positive shifts.

Theme: Variability in students' self-efficacy based on previous experiences in math. The students' math confidence varied as they used mathematics for engineering design work. Seven students shared being more confident in their abilities to complete difficult math tasks. For example, Braksten's described feeling anxious when faced with using math in an engineering project:

> [I was] nervous when we had to do the math with engineering with the engineering project, it changed when we kept working on [the] engineering design project... When we were figuring out how much sand and gravel [that] is needed to keep our flowrate where it should be, I felt that I could do the hard math, and I felt confident.

Jessy focused on confidence and using abilities that she thought she possessed at the onset of the unit. She said, "[I felt] happy because now I know how to do other kinds of math I didn't know I was doing…. When we were doing the sand part of math to figure out the flow rate, it made the hard math easier." Here, the "sand part of math" refers to calculating the correct ratio of sand along with the other materials, such as charcoal or gravel, used in their prototype. While variability in students' math self-efficacy was present throughout the unit, students' highlighted feeling more confident in the math abilities after completing the unit.

Theme: Integration was a value-added experience for students. Ten students expressed positive beliefs in their math ability, even if they perceived that the math was hard to learn. Two students believed the source of their positive mathematics self-efficacy was perseverance. Anhelica said, "Depending on what math it is, I think I'm okay [at] math, I think I can persevere through it even on difficult math." Besides perseverance, Rylan focused on a fondness for mathematics. Rylan said, "I feel good in my math abilities. I like learning math [and when] trying to learn something new. I try, and if I fail [I] just keep trying." The integration of engineering and mathematics also fostered opportunities for students to develop their mathematics self-efficacy. Michelle noted, "[I'm] not that good [at math] I can't really solve it that good... I have to get the teacher's help...When math is hard, I can learn it...[The math] was a little hard [to learn]. We had to use calculators. I know it's easier to divide because of doing math and engineering...I like that I can do [the engineering math], so when I knew [it was hard math] I got scared... I didn't think I could do [the math]. I don't have that feeling anymore."

Summary of Qualitative Results

Overall, students described the mathematics conducted during their integrated engineering unit as hard or difficult. However, many also described an increase in the confidence to do difficult math at the unit's end. The connections between the unit, students' previous experiences, and their current self-efficacy beliefs in mathematics show a complex and interactive system of beliefs fostered through students' educational experiences.

Mixing of Results and Discussion

Our qualitative analysis revealed that students possessed positive general mathematics self-efficacies, which was expressed when students spoke about their past math experiences. According to Marsh and Graven [30], students should have positive beliefs about their capabilities at the onset of tasks. However, initial self-efficacy beliefs may not align with students' capabilities based on the task's nature and can undercut students' self-efficacy [31]. Quantitatively there was a reduction in students' self-efficacy in this study. However, students also qualitatively demonstrated positive self-efficacies for completing hard math tasks. The mixed results indicate that students may be calibrating their self-efficacies based on their experiences during the integrated unit [32]. Alignment between students' self-efficacies and task expectations supports increased learning and persistence [33].

Perceived usefulness findings indicated conflicting trends. While no significant differences were found between time points for perceived usefulness, students' discussed the usefulness of engineering mathematics across multiple aspects of their present lives and future goals. This apparent contradiction in the data may stem from the survey questions' focus compared to the interview questions. Perceived usefulness is highly dependent on context [2], and when examining the questions the, "engineering math" context discussed by the students in the qualitative interviews is not present. Additionally, it is possible that these positive perceptions of usefulness existed before the unit and were unaffected by students' experiences in the unit. Maintaining positive perceptions of math's usefulness throughout a unit with "hard math" indicates the potential for integrated units to limit the decline of students' attitudes toward mathematics.

Limitations and Future Work

This exploratory mixed-methods study represents a first step in exploring the self-efficacy and perceived usefulness beliefs of 5th-grade students with respect to mathematics, following their participation in a science, mathematics, and engineering integrated unit. The explicit and intentional focus on a single classroom to understand the influence of implementing an integrated engineering unit limits the quantitative results' power and the ability to establish reliability and validity for our survey. Given this work's initial positive trends, future work should expand this study to a larger population to address the aforementioned quantitative limitations. Additionally, the students' qualitative responses may have drifted from the focus of the original quantitative surveys. As such, additional piloting of both data collection instruments to ensure alignment across both is needed. Finally, the results presented here intentionally focused on students' perceptions of their beliefs and did not examine students' performance on their mathematics in the unit or related assessments. Future research expanding this work should cross-examine students' performance on key measures alongside their perceptions to determine the accuracy with which students are calibrating their beliefs.

Conclusions

The combined results indicate students' self-efficacy and perceived usefulness beliefs can be shaped by experiences with an integrated engineering unit. Students' self-efficacies across disciplines intersect to shape the beliefs. Our findings present mixed evidence of the impact of an integrated unit on students' mathematics self-efficacy. Students' survey responses suggested declines in math self-efficacy and no significant changes in engineering self-efficacy and perceived usefulness of math. Qualitatively, we learned that students see math's usefulness in their lives and feel that they can do hard math alongside engineering. Taken together, we observed that intentional integration of STEM disciplines ensures that students can feel confident about their abilities to use and perform in mathematics.

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Appendix A
Lesson Plan: Conservation of Mass and Operations and Algebraic Thinking

Materials:
- 8 oz plastic empty cups
- tap water
- set of mass pieces
- pan balance
- salt
- measuring spoons

Prepared materials:
1. 8 oz plastic cups with water
2. 8 oz plastic cups with dissolved salt
3. empty cups
4. tap water

Overview:

The 45-60 minute lesson covered the connections between the conservation of matter and algebraic thinking. The experiment's objective required the student teams to figure out if there was anything in a clear solution. Following this, the students write a mathematical equation for the solution. The teacher taught the students how to use a pan balance with the grams weights to determine the weight of objects. The student teams had two prepared cups of liquid, along with empty plastic cups and tap water. The teacher informed the students they couldn't dump out any of the liquid in the prepared cups. Each team determined the mass of both prepared cups was not the same.

The teacher wrote the gathered information generated by the class (bullet points) on the whiteboard and required the students to use the two questions to generate their equation.
- The weight of an empty cup,
- The weight of the cup and water,
- The weight of the water
- The weight of the cup with an unknown substance

(Questions used to help the students generate the equation)

1. What information from the displayed information is needed to figure out the weight of the unknown substance?
2. How would you use math to figure it out?

Instruction guide:

Before the student teams began their work, the teacher conducted a "math think aloud," using the weight of an empty cup and the weight of water with the students. Each student team determined the information from the whiteboard they needed to achieve an answer. Once the teams develop an answer, the teacher gave a direct instruction lesson on how to write mathematical equations and expressions using the students' team information. Once they predicted the weight, the students then used the method of evaporation to verify their ultimate answer. The teacher gave the students step-by-step directions on how to evaporate the liquid. The following day the students checked the weight of the unknown substance and identified the substance by using a key. How to write expressions and equations based on information generated in the lessons was reinforced throughout the unit. How evaporation is used to clean water was covered in future lessons.

Appendix B

POST UNIT INTERVIEW QUESTIONNAIRE

This interview is voluntary and you do not have to answer any of the questions if you do not want to. I will ask you several questions in order to better understand your experiences during the unit.

Teacher: _________________ Date: _________ Grade: ______ NAME/ID #_________

What parts of the unit made you feel confident about your math ability? What parts of the unit did not make you feel confident about your math ability? What about the unit made you feel this way?

Open-ended Questions

Math Ability

1. What do you think about math? How do you see yourself as a math student?
    a. Why do you feel that way?
2. Has math usually/generally been easy/hard for you?
    a. How did you do in math in your previous grades(4th)?
    b. Do you like learning math?
    c. Do you think it's hard to learn math?
    d. Can you think of an example of a time when you liked learning math?
    e. Can you think of an example of a time when you disliked learning math?
    f. What happens when you are trying to learn a new idea in math?
    g. When a math idea is hard, do you feel like you can still learn the idea?
    h. Do you feel like you can learn the math that's taught in our class?

Math Usefulness

3. What do you think about learning math with engineering?
    a. After using math and engineering together, has your view of math changed? Why has it changed? Why hasn't it changed? How has it changed?
    b. Do you feel you can use math for your engineering projects?
4. If your view changed, what parts of the project made this happen?
5. Was it difficult for you to learn math with engineering?
    a. Have you used math in engineering before?
6. Do you think you'll use the math you're learning in this class in the future?
7. Have you come across any ways that math is used outside of school?
    a. Is that math easy or difficult?