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MEAS: EXPLORING LINKS BETWEEN IMPLEMENTATION AND STANDARDS MASTERY

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In order to effectively enhance a student's mathematical understanding and development in the field of mathematics, students need to engage in problem solving. Model eliciting activities, or MEAs, provide students with tasks that promote higher level thinking and the ability to utilize mathematics outside of the classroom; they also align and promote the utilization of the Common Core State Standards and Standards for Mathematical Practice. Research suggests that the language and motivation promoted by MEAs enriches engagement and increases student ability and performance of traditional and real-world mathematics. Use of technology further supports these goals. Through the analysis of checkpoint quizzes and a post-assessment of groups using and not using MEAs, I discovered the impact of MEAs on student performance and test scores. As a review tool, with no previous MEA exposure, traditional review and MEA review did not produce significantly different results. For more conclusive results, collecting data from a student group already familiar with MEAs before data collection would likely generate richer data for study.

Introduction

The National Council for the Teachers of Mathematics (NCTM) defines problem solving to mean "mathematical tasks that have the potential to provide intellectual challenges for enhancing students' mathematical understanding and development" (NCTM, 2016). These tasks seek to promote students' conceptual understanding, foster their ability to reason and communicate mathematically, and capture their interests and curiosity (NCTM, 2016). This research has shown that only when students engage in true mathematical problem solving, involving significant mathematics, can teachers ensure students experience necessary intellectual contexts to develop mathematically. According to NCTM, "only 'worthwhile problems' give students the chance to solidify and extend what they know and stimulate mathematics learning." (NCTM, 2016). Worthwhile tasks should be interesting and have a level of challenge that invokes deliberations and thought-provoking work. These tasks should also direct students to examine important mathematical ideas and ways of thinking toward desirable learning goals (NCTM, 2016).

In order to help students become successful problem solvers, teachers need to not only commit to problem solving in their math curriculum, but also need to provide problem solving tasks to create classroom discourse to maximize learning opportunities (NCTM, 2016). This includes: "(a) finding multiple solution strategies for a given problem, (b) engaging in mathematical exploration, (c) giving reasons for their solutions, and (d) making generalizations" (NCTM, 2016). Having a focus on problem solving in the classroom not only impacts the development of students' higher order thinking skills, but also reinforces positive attitudes like motivation, discussion, and creativity (NCTM, 2016). Modeling tasks can accomplish these goals. "Modelling contributes to students' problem-solving capabilities, and to their collaboration and critical thinking skills" (Takači & Budinski, 2011, p. 33). Modeling has the potential to maximize learning opportunities and potential for higher order thinking.

Daher and Shahbari (2013) describe mathematical modeling as the method of representing real-world problems or circumstances in a mathematical way to understand and seek solutions to these problems. Given this description, a mathematical model can be considered an outcome of mathematizing (putting into math terms) a real-world problem (Daher & Shahbari, 2013). A model eliciting activity (MEA) utilizes this mathematical modeling in "real situations, where it contains incomplete, ambiguous or undefined information of the situation. The students are required to interpret and make sense of the situation in a meaningful way" (Daher & Shahbari, 2013, p. 26). These typically small group activities task modelers to share the responsibility for developing their model. This develops both mathematical argumentation and communication as students describe, explain, and justify their opinions to each other (Shahbari, 2017). The activity itself necessitates student engagement because of the responsibility to justify their thoughts and mathematics.

This engagement is a cyclical process "involving iterative cycles of translation, description, explanation, and prediction of data outcomes and solution paths" (Shahbari, 2017, p. 722). The cycle begins with introducing students to a real-world situation with the end goal being to develop mathematical thinking. As students progress through the cycle, they work from given data and goals, test their theorical model, manipulate and revise their solutions, and draw conclusions they can justify as correct (Takači & Budinski, 2011). Throughout their work, students are constantly aligning their work with previous renditions and communicating their thoughts with others in the class. These modeling tasks are designed to help students understand modeling and ultimately, their model will be simplified to address specific math goals and standards (Zbiek & Conner, 2006). By engaging in this cycle within mathematical modeling, students are more motivated to engage in deeper learning and a more authentic view of mathematical concepts. These activities encourage and motivate students to apply information they have learned to the modeling process. “Unlike traditional lecturing, modeling in high schools improves the quality of student learning process and fosters deeper learning” (Takači & Budinski, 2011, p. 33). With this in mind, I intend to investigate the impact of MEAs and their outcomes on student learning.

Throughout this paper, I will be analyzing research regarding MEAs to support the claim that MEAs deepen and enrich students' understanding of mathematics through their alignment with the NCTM and CCSSM standards, their ability to elicit motivation and student engagement, and their appropriate utilization of language and technology. I collected data about the implementation of MEAs as a review tool in my classroom research in order to gauge its effectiveness generally. My procedures, results and conclusions follow the literature review. With this research, I hoped to not only to implement a modelling task, but also discover the impact on student learning and future classroom use.

Literature Review

The purpose of my action research is to explore the use of MEAs as a retention tool for classrooms assessments, and more importantly, a tool to aid student understanding of the mathematics content standards being taught. It is necessary to understand the alignment of MEAs to the Standards of Mathematical Practice and how they can be utilized for student proficiency in the Common Core State Standards for Mathematics. It is also necessary to establish, through research, how MEAs motivate and engage students within mathematics and how they may lead to a deeper understanding of mathematical concepts. The role of technology and precise mathematical language within MEA implementation will also be explored and discussed.

MEAs and Standards

Modeling tasks can promote specific outcomes for mathematics education, such as the Common Core State Standards for Mathematics (CCSSM) and the Standards for Mathematical Practice (SMPs). In fact, MEAs rely heavily upon NCTM's SMP 4 which states that "mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace" (CCSSI, 2010). Floro and Bostic (2018) investigated 38 middle school teachers participating in year-long professional development with the goal of fostering sense-making of Common Core Standards and SMPs through tasks promoting modeling with mathematics.

Two themes arose from their qualitative case study: structure in mathematics and language. When it came to structure in mathematics, "each teacher who conducted a modeling with mathematics task shared how students struggled with the inherent mathematical structure within the assigned problem" (Floro & Bostic, 2017, p. ##). Two selected teachers, Mr. Brown and Mrs. Zelda, engaged their students in exploratory mathematics tasks to deepen their understanding and promote modeling with mathematics. In both situations, the teachers attended to situations within their post-lesson interviews where students demonstrated difficulty connecting the meaning of situations to terms within their created/discovered equations. Both teachers used multiple representations and aimed to assist students to transfer knowledge using one representation (e.g., graph or table) to another (e.g., expression or equation). Concurrently, these teachers felt the need to foster their students' sense making of mathematical structure through various methods of instruction. Mr. Brown explicitly demonstrated for students a way to manipulate one mathematical structure while Mrs. Zelda scaffolded students' thinking through different examples that might foster greater connections and correct the misconception. While each teacher led students through misunderstandings differently, both noticed the importance structure within the task. "It was clear from these teachers' voices that looking for and making use of structure within these tasks addressing SMP 4 is important" (Floro & Bostic, 2017, p. ##). This demonstrates that for students to effectively engage in MEAs, they must demonstrate fluency in mathematics, understand and align to the SMPs, and be able to engage these SMPs when completing the activity. In response to the students' variance in mathematical fluency, teachers can engage students both deliberately (like Mr. Brown) or more abstractly (like Mrs. Zelda) and still achieve positive and rich outcomes that MEAs provide. While students in Mrs. Zelda's class were led to discover their own structural conclusions, the students working with Mr. Brown were able to see these real-life conclusions modeled by their teacher, leading Mr. Brown to believe that next time, his students may be able to draw these conclusions on their own. These flexible thinking structures allow students to generalize various methods of problem-solving and apply critical thinking skills to situations beyond mathematics and the classroom.

While the above study focused on mathematical structure, the following research suggests that SMP 4 not only promotes this use of structure, but also many other core mathematical beliefs. In their study, Bostic and Matney (2016) conclude that teachers who promoted SMP 4 "were associated with fostering mathematical behaviors and habits found in at least one and possibly up to six additional SMPs" (Bostic & Matney, 2016, p. 24). They found that when teachers focused their classroom teaching on the promotion of SMP 4 that engagement in other SMPs occurred without explicit instruction. Through these fostered connections within

SMPs, a student has the ability to make sense of mathematics at a deeper cognitive level by drawing on SMP 4's standard of building connections between mathematics and the real world. Bostic and Matney conclude that SMP 4 focused instruction is likely to engage students in the skills and practices within other SMPs because this "instruction offers opportunities for students to engage in mathematics within tasks drawn from relevant contexts and connect ideas among various situational contexts." (Bostic & Matney, 2016, p. 29). By design, MEAs that engage students in SMP 4, encourage them to apply mathematics by modeling, and by extension, engage other SMPs.

In addition, the use of modeling has shown to increase student performance both on traditional mathematical assessments and application of these assessments in the real world. Boaler's three-year longitudinal study (2001) examined students who engaged in open-ended, project-based instruction and modeling. These students outperformed their peers who were taught in a traditional setting, even though the national examination questions were unlike the open-ended approach by which they had been taught or were accustomed (Boaler, 2001). Because of this significant difference in performance, "Educators have proposed that students engage in mathematical modelling as such learning situations can encourage students to develop a deeper, conceptual knowledge of mathematics" (Boaler, 2001, p. 127). Key to this conceptual development is the mastery of purposeful mathematical discussion and language.

Language

In the Boaler study (2001), students who engaged in modeling were more likely to see mathematics as applicable and used outside of the classroom setting. Because the mathematics instruction utilized real-world situations and the language of those situations, students were more likely to see mathematics applied in multiple and differing settings (Boaler, 2001). This discussion more realistically mirrors real-life mathematics, thus fostering more authentic engagement and learning. Teacher practitioners of MEAs have found that this discussion is “central to [student] engagement in the modeling activities” (Shahbari, 2017, p. 734). SMP 6 promotes teachers and students alike to “attend to precision” (CCSSI, 2010). Part of this precision includes precise and intentional use of mathematical language. Student should be trying to use clear definitions in discussion with others and their own reasoning…and make explicit use of definitions” (CCSSI, 2010). In the study by Floro and Bostic (2017), precision of language emerged as a major theme in the process of problem solving. This study revealed that while working through problems involving modeling, teachers attended to students’ precise use of mathematical language, as well as their own, during instruction. Mr. Brown found that taking the time to help students with mathematical language not only helped students with understanding terminology, but also helped them to manipulate the real-world problem with regards to its context. This ability to work both within and without context “allowed [students] to create more appropriate mathematical models,” ultimately leading them to more viable solutions with appropriate, justified, contextualized solutions (Floro & Bostic, 2017, p. ##). This focus on breaking down the task’s language is important because for students to understand modeling with mathematics tasks, they need to understand the language embedded within it. Without this understanding, they will not understand the problem, let alone create models to solve it (Floro & Bostic, 2017).

Bostic and Matney observe this precision of language and its later utilization in their observation of SMP 4. They observe Mrs. Gaston interacting with her students during a task that requires modeling, noticing that they often “asked one another to tighten their language” while they were justifying their models (Bostic & Matney, 2016, p. 28). Precise communication aided students in building the connections between symbols and their meanings, number sentences, and graphic representations. This communication not only solidified vocabulary but also improved student understanding of mathematical ideas (Bostic & Matney, 2016). This attention to mathematical language represents many levels of cognitive function—understanding terminology, the mathematics the language represents, and the application of those terms to real-world situations. Beyond clear definitions, SMP 6 states that students will eventually learn "to examine claims and emphasizes the explicit *use* of definitions" (CCSSI, 2010). Students are expected to move beyond simply understanding definitions to the utilization of language as they progress to higher levels of mathematical reasoning. As Floro and Bostic (2017) observe, MEAs utilize multiple cognitive facets regarding SMP 6, including "reading text and other mathematical representations, connecting those representations, and drawing upon them during further problem solving" (Floro & Bostic, 2017, p. ##). This study demonstrates that MEAs allow students to apply learned mathematical terminology and practices to later problem-solving experiences. Beyond terminology, MEAs support broader mathematical communication skills that will help to facilitate not only problem solving, but also engagement in the standards that the MEA addresses.

Motivation and Engagement

Mathematical modeling asks students to engage at levels beyond mathematics itself, as it engages students in real-world situations. The multiple paths that modeling offers also encourages student engagement. As Shahbari observed in interviewees, "an undefined solution path can be associated with more positive attitudes such as motivation and curiosity (Shahbari, 2017, p. 732)." Because of this potential for multiple models, these scenarios "[engage] students with different social, mathematical, and communicational processes" (Daher & Shahbari, 2013, p. 25). This engagement, in turn, offers more possibilities for motivation than other types of problem solving since it allows "students a wide range of learning possibilities, and thus motivates them to learn mathematics" (Daher & Shahbari, 2013, p. 25). Given the extent of these possibilities, motivation can be developed through various avenues.

According to the study by Zbiek and Conner (2006), motivation during mathematical modeling tasks can be broken down based on different mathematical and social appeals. It occurs because real world problems appeal to some learners who become excited by the real-world context and mathematical connection. It occurs when students feel the need to study the complexity of mathematics because they now see it as a tool to tackle that complexity. Finally, it occurs because the student engaging in modeling does not possess the mathematical understanding needed to create their model and actively seeks out the needed mathematics (Zbiek & Conner, 2006). Each of these motivations asks students to engage in mathematics in a way that is unique to them as a learner, providing a more conducive environment to foster mathematical understanding.

This type of motivation and engagement opens the door for more complex mathematics and cognition. Lesh and Harel (2003) observe that MEAs allow for these mature levels of thinking to emerge. To engage as mature thinkers, students must begin to organize thoughts around abstractions over experiences. MEAs allow for this to occur when students engage in conceptual tools that are reusable and sharable, are introduced to powerful means for representation that help construct meaning, and are also encouraged to move their thinking beyond those constructs (Lesh and Harel, 2003). Whether or not students reach this hoped-for level of complex thinking, engaging in the MEA keeps that potential open and secures the possibility for *some* mature mathematical thinking to begin.

This potential for deeper mathematical thinking seeks to develop competencies that can help students in future life and workplace situations. As Abassian et. al. (2019) observes, these mathematical models provide a platform for students to “engage in mathematics in robust ways” (Abassian, et al., 2019, p. 63). Furthermore, the modeling they refer to elicits motivation for mathematics itself, as students begin to understand the need for learning mathematics (Abassian, et al., 2019). In fact, the study by Boaler (2001) found that students who engaged in modeling were more likely to see “no differences between mathematics of school and the real world, and that in their jobs and lives they thought back to their school mathematics and made use of it” (Boaler, 2001, p. 124). Students who engage in these models not only see the need for mathematics but begin to see its potential for use in their future lives as problem-solvers. This subsequently helps to motivate engagement in the classroom setting.

In the article by Bostic (2015), Mrs. Bosetti observes that when students engage in a modeling task, they are more excited and engaged and are not just working with mathematics—they are using it. She says, “I don’t worry about [explicitly] teaching math when I do modeling problems like the Dairy Queen Dilemma because students are *doing* mathematics” (Bostic, 2015, p. 357). Because of this shift in the role of the teacher and student, the learning and cognitive development takes place primarily through the students’ paths, not the teachers. This appeals to each student’s individual needs based on their personal readiness and therefore can help all students learn and retain the concepts they are working with. One of the tools that can help differentiate these levels of readiness can be the utilization of technology.

Technology

MEAs can greatly benefit from the use of technology tools that enable students to create and manipulate their model in real time. When working with students within a modeling task involving exponential equations, authors Takači and Budinski (2011) were able to utilize *GeoGebra* in order to help students visualize and connect exponential functions to real world scenarios. Through this technology tool, students were able to “highlight various cases of exponential functions and bring out their own mathematical conclusions” (Takači & Budinski, 2011, p. 37). SMP 5 delineates the use of technology when creating mathematical models, asking students to utilize technology “to visualize the results of varying assumptions, explore consequences, and compare predictions with data” (CCSSI, 2010). Furthermore, these technology tools should be used to “explore and deepen their understanding of concepts” (CCSSI, 2010). In the *GeoGebra* example, the technology utilized gave students the ability to visualize and therefore deepen their understanding of exponential functions, helping to make things less abstract, more concrete, and easier to comprehend. With these technical tools in place, students are more able to visually represent real world scenarios in their own models. Consequently, they gain more understanding and can better communicate those models and the mathematics behind them.

Daher and Shahbari (2013) had similar success with technology when working with 30 pre-service middle school teachers, none of whom having previous experience with MEAs. When working through the “Summer Reading Activity” MEA, technology helped the preservice teachers build the conceptual systems to create a successful model for the problem, because the technology provided technological working options which helped them formulate mathematical ones. These technology-based models further allowed these pre-service teachers to easily test their models through the digital tool in order to put the model to the test. The technology tools used by the pre-service teachers in the MEA allowed for this improvement of the model to take place, as well as allowed them to interpret their results back to the “Summer Reading Activity” (Daher & Shahbari, 2013). Through strategic implementation of technology within MEAs, participants can create environments of meaningful learning which not only provide the opportunity for clear visualization and understanding, but also engages “learning which includes rich mathematical conjecturing and investigation, as well as rich mathematical discussions and justifications” (Daher & Shahbari, 2013, p. 43).

These examples demonstrate the usefulness of technology when utilizing MEA instruction. The tools allow for efficient creation and testing of models, as well as test predictions, assumptions, and consequences, which allow for a deeper and more comprehensive understanding of concepts. In the Daher and Shahbari article (2013), the authors emphasize that the use of technology has even more far-reaching importance, as the world is increasingly more technological and information-based. The use of technology in MEAs allow students to develop abilities that “enable them to function as more flexible, creative and future-orientated mathematical thinkers and problem solvers” (Daher & Shahbari, 2013, p. 42). These technology tools are not useful in and of themselves, but as a means to achieving a greater understanding of mathematics and the real-world problem solving at hand.

MEAs offer the flexibility and open-endedness that students need to explore mathematics in a way that is meaningful to them. With luck, they will also serve to assist students in mastering the standards in a more comprehensive manner.

Methodology

The purpose of my research was to determine the impact that MEAs have on student achievement. If students participated in MEAs over the course of a unit of regular mathematics instruction, would they demonstrate a higher competency of the standards than those who did not?

Participants

At Rossford Jr./Sr. High School, I had two sections of algebra (mostly 9th graders). Each section consisted of 25 students per class, with a majority of said students being Caucasian (80%). One in three students qualify for free and reduced lunches.

Procedure

The experiment took place during the instruction of one unit in the second semester. Two quizzes were used to gather evidence of student knowledge of learning objectives during checkpoints of the unit, with each of these quizzes taking place shortly after the material instruction. The data from these quizzes were used as both summative and formative assessments. Both groups participated in these quizzes with this data demonstrating both individual and class mastery of learning objectives. This data was collected and used comparatively with their post-assessment scores for the unit. During this unit, class one engaged in a modeling task after regular instruction finished. Class two participated in an equally engaging, more traditional review, such as a Kahoot or Jeopardy, to review material. The same post-assessment was given to both class one and two once again to determine content knowledge. The post-assessment consisted of the same type of the questions as the previous two quizzes, measuring the same learning objectives. Additionally, objectives that students learned but were never quizzed on in the checkpoint quizzes appeared on the post-assessment as a means of gaging the modelling task or review and the ability of each review method to prepare students for material they had not been tested on previous to this assessment. At the end of the unit, the collected data from the assessments was used determine to whether each student performed better during their post-assessment with the addition of the modelling task.

I tabulated the results of all three assessment scores for every student in both classes. I then compared each students' performances both with and without the utilization of the modelling task. I calculated level of mastery for each student and learning objective from all three assessments for the unit. I then compared the percentage of change for each learning objective both with and without the modelling task. I also calculated the class average for both classes to find the average percentage change for each of the six groups of data.

Based on research I have done in this paper, I hypothesized that when students participated in modelling tasks within classroom instruction, I would see a greater increase within their post assessments scores than those who did not participate in the modelling task.

Modeling Task

Class one participated in a modelling task created by me in which they engaged in a task requiring them to factor eight expressions to find the "length and width" of eight rooms. Students were split into groups of four and able to work with each other to complete the task. Once students factored each expression, they were asked to come up with two x values (one for each "floor") to find the "area" of four rooms located on each floor. Students were allowed to arrange the eight rooms between either floor to ensure that the expression they chose for the floor would work for their given x value. Once students selected each set of rooms for both floors, they were asked to create a floor plan of each of the two floors and label their plan with the location of each room. Students were allowed to arrange their rooms in any orientation to best create their homes. Once the rooms were arranged for each floor, students were asked to find the total area of each room and the total area of the floor. Additionally, students were given access to the review used for the other class in order to allow them to see material and questions that would be asked of them on the assessment. Included below are the instructions that students received when working on this modeling task.

Instructions. Today, you will become contractors. A family has approached you to design their house. They know what they want the area of each of the rooms to be and have provided a list of those areas. But they don't know how they want these rooms arranged or what the dimensions of the rooms are. Your job is to help the family by finding the best layout of the rooms given that each floor will consist of four rooms. Follow the steps provided to help you design the house you believe best fits the family's needs.

1. Factor each room to find the dimensions of each side.
2. Find a value for x for both the first and second floor that will make the rooms a reasonable size.
    a. X does not (and probably will not) be the same for each floor.
    b. Plug in your x for each factor to ensure it is a positive side length.
3. Arrange the rooms between the two floors based on the x value for each floor to try to minimize the amount of wasted space between rooms. Four rooms are going to be on each floor. Those rooms can be on any floor and can face any direction.
4. Once your rooms are arranged, find the final area of each room and floor.

There is no right answer to this question so do not be afraid to use some guess and check and problem-solving skills to find the layout that your group believes to be best. If you get stuck, make sure to ask questions. Do not be afraid to use the algebra tiles to help you find the dimensions of the room, help you arrange your rooms, and "build" each of the layouts for each floor.

Area's of Each Room:

Room 1) $3x^2 - 2x - 5$

Room 2) $x^2 - 4$

Room 3) $x^2 + 8x + 7$

Room 4) $x^2 + 3x + 10$

Room 5) $x^2 + 6x + 9$

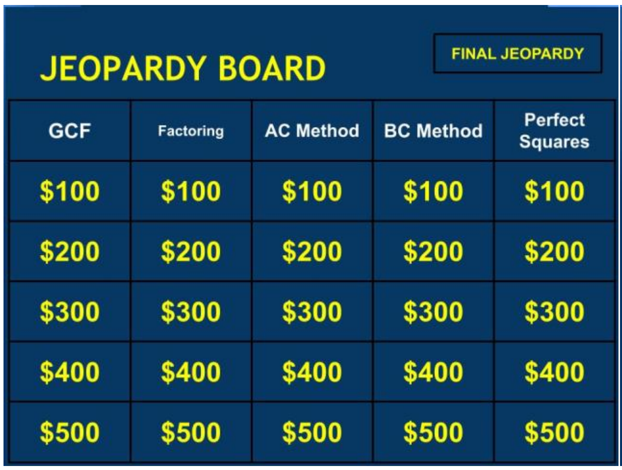
Room 6) $x^2 - 5x + 6$

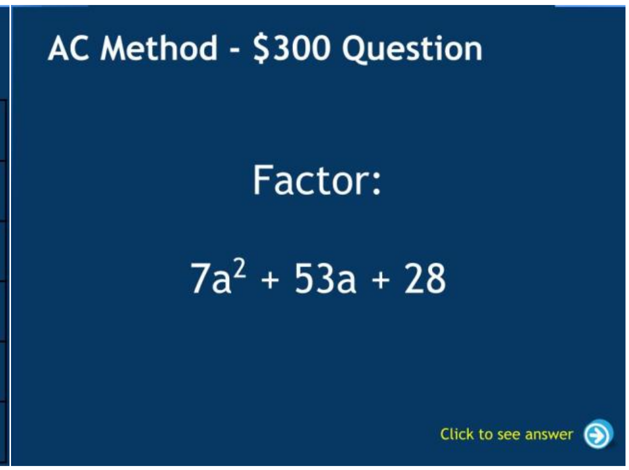
Room 7) $2x^2 + 3x - 9$

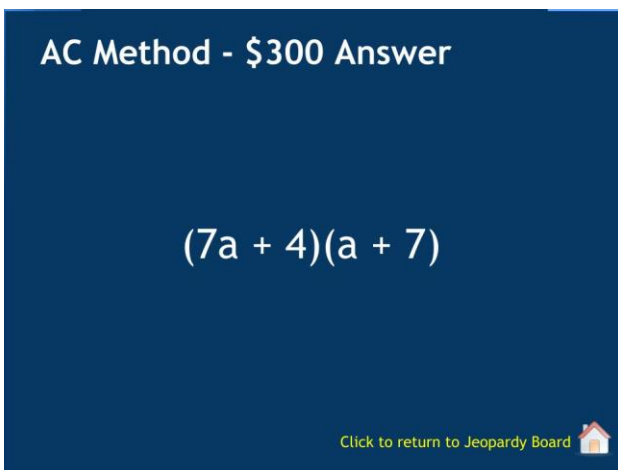
Room 8) $x^2 - 2x + 1$

Jeopardy

In order to provide a review that I felt had a similar level of engagement to the modeling task, I created a Jeopardy review for the other class. Students were split into six teams and were allowed to pick a question of varying difficulty to answer as a team. Questions were directly related to the learning objectives focused on within the unit. Unlike traditional Jeopardy, in which the fastest person with the correct answer remains in control of the board, each team selected the question they wished to answer and had the appropriate amount of time to find the answer. Control of the board was then given to the next team. If they missed the question, it went to the next team for a chance to “steal.” Starting with team one and going through each team, I fascinated the board, answers, and points until class ended. Below are the categories for review and an example question from the Jeopardy Review.





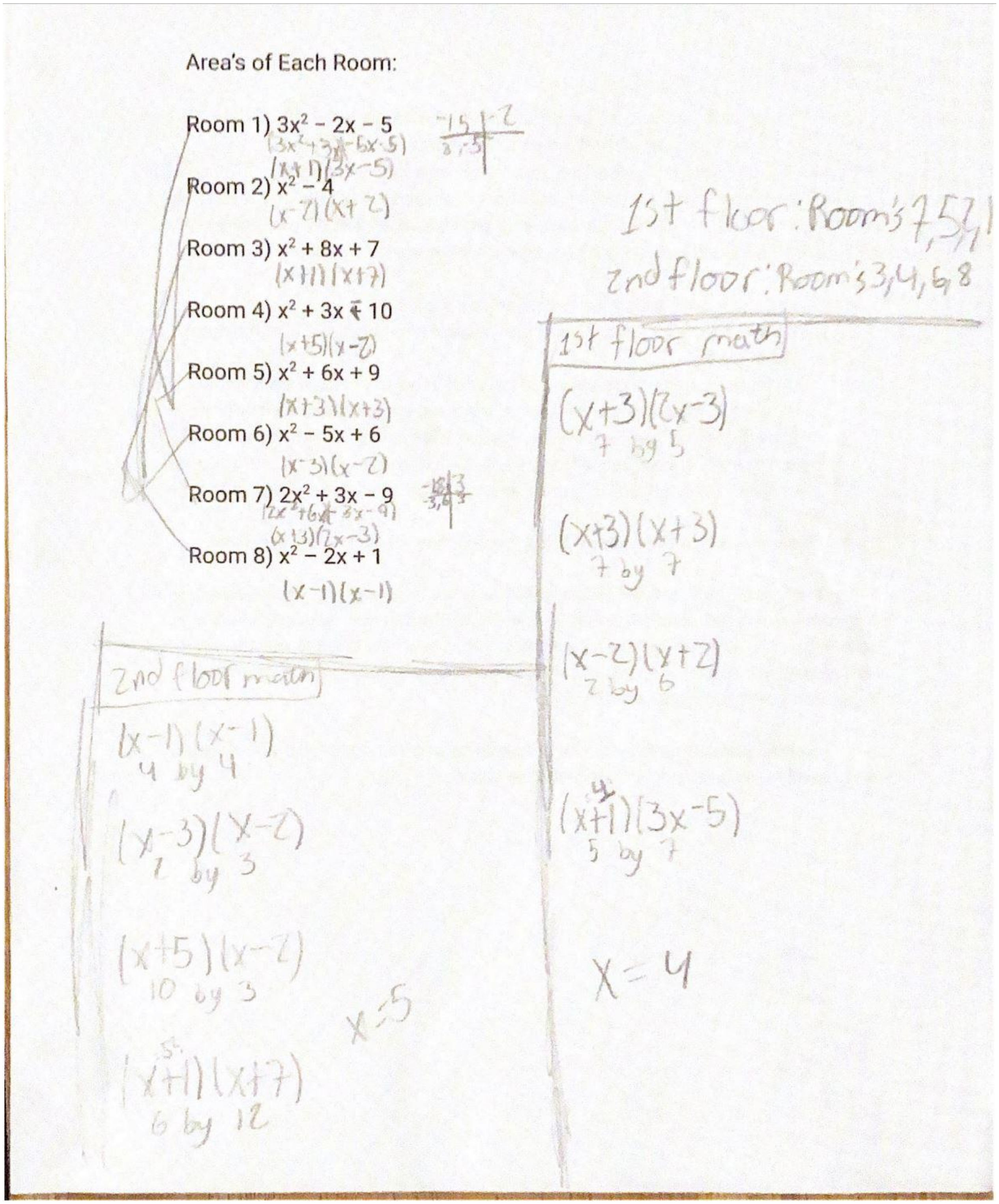


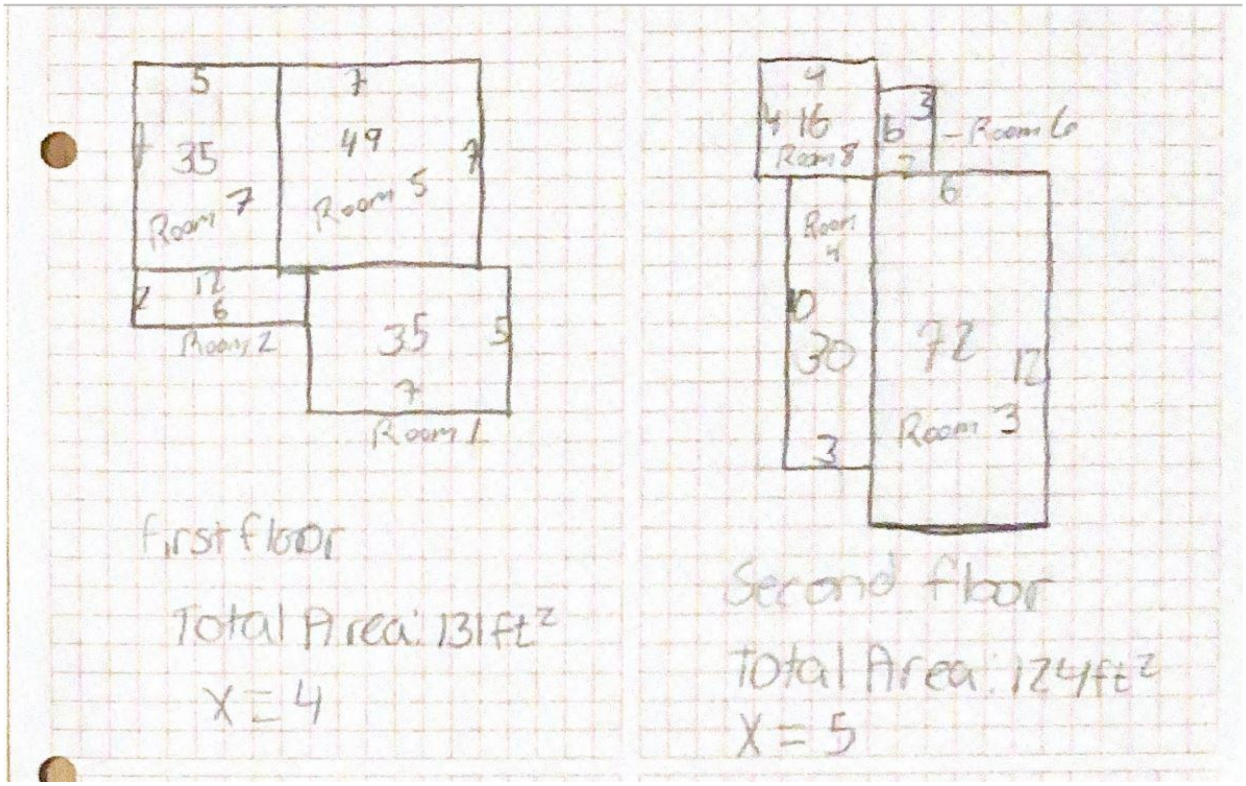
Results

Review Results

Overall, both reviews went well. Students were engaged in the material and gained experience with the knowledge and learning objectives they were about to be assessed over. The Jeopardy group got through about 2/3 of the questions, with at least the $300, $400, and $500 questions in each category being addressed. The modeling group at first struggled to comprehend what was being asked of them, with this being their first time experiencing a modeling task. Once students got started on the task, my cooperating teacher and I were able to answer any questions that arose and help them with factoring, selecting an x value, and helping them to see what the task was asking of them when arranging their rooms. With this help, students better understood the task and were able to arrange their floor plans and find their areas. Below is a student work sample of the completed modelling task.

Student Work Example





Assessment Results

Learning Objectives

The learning objectives (LOs) measured within the first checkpoint assessment (Quiz 1) include:

1. Students will be able to (SWBAT) Factor a monomial down to its prime factorization and variables without exponents (LO1).
2. SWBAT Find the GCF between two monomials (LO2).
3. SWBAT factor a two-term expression by finding the greatest common factor (GCF) between the two terms (LO3).
4. SWBAT factor by grouping (LO4).

The LOs measured in the second checkpoint assessment include:

5. SWBAT Factor a quadratic equation when a = 1 (LO5).
6. SWBAT Factor a quadratic equation when a is not equal to 1 (LO6).
7. SWBAT identify a, b, and c in a quadratic equation (LO9).

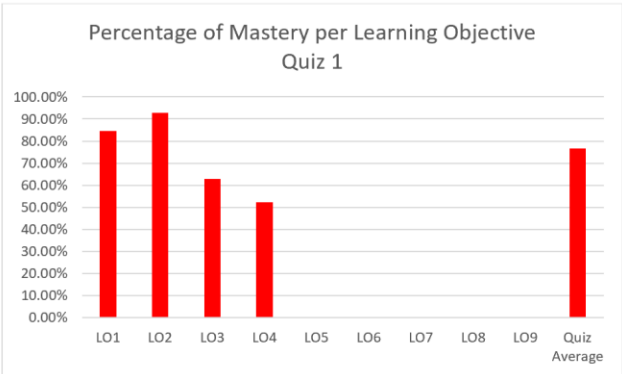
The LOs measured in the third assessment (Factoring Test) include all of the previous and:

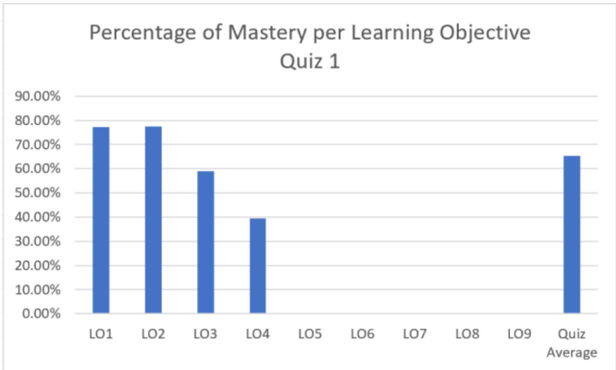
8. SWBAT to Factor using the difference of two squares (LO7).
9. SWBAT to Factor by using multiple methods of factoring (LO8).
10. SWBAT determine how many terms are needed to be able to factor by grouping (LO10).

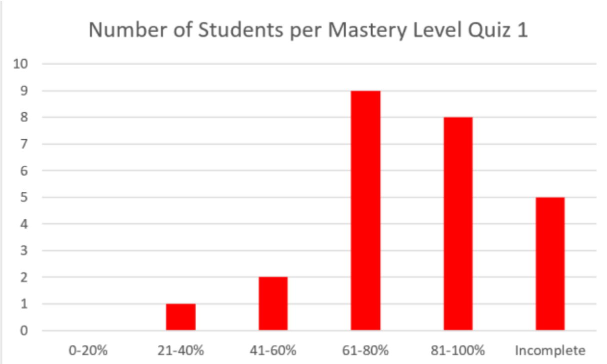
Before the final assessment was distributed, additional review for both classes of each of the LOs was provided by me. This included demonstrating the problem-solving required to perform each of the LOs through an example problem.

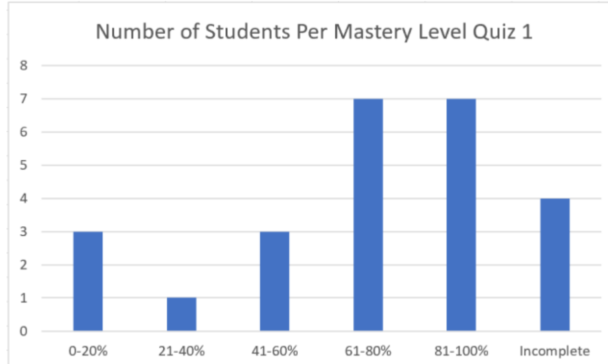
Data

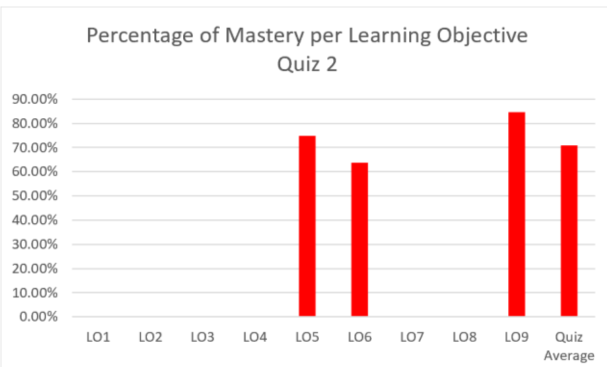
Provided below are 12 graphs. The graphs with red bars are the results of the students that partook in the modelling task for review (class one). The graphs with blue bars are the results of the students that partook in the Jeopardy Review (class two). The two charts I chose to create for each assessment analyze the percentage of mastery for each LO and the number of students who have reached each level of mastery of all LOs in the given assessment.

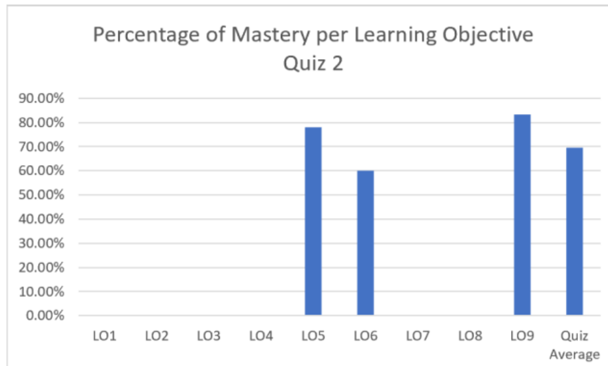


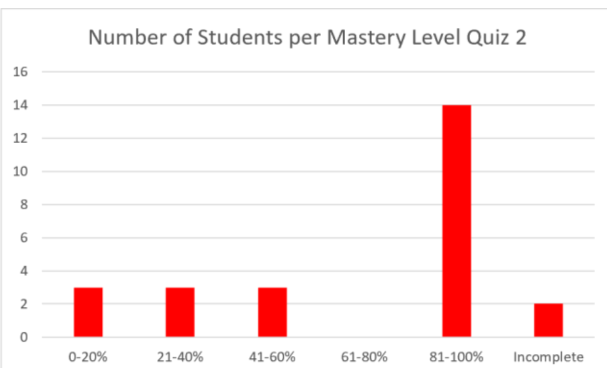


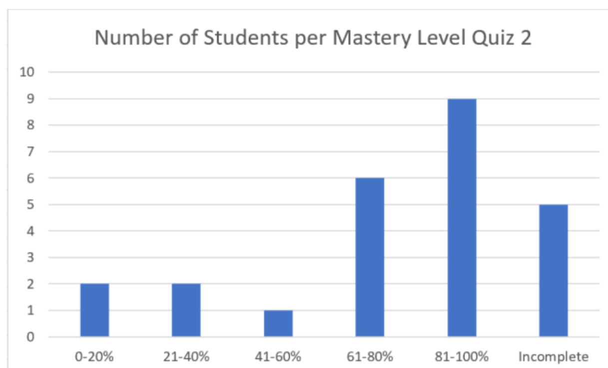

Number of Students per Mastery Level Quiz 1
10
9
8
7
6
5
4
3
2
1
0
0-20%
21-40%
41-60%
61-80%
81-100%
Incomplete

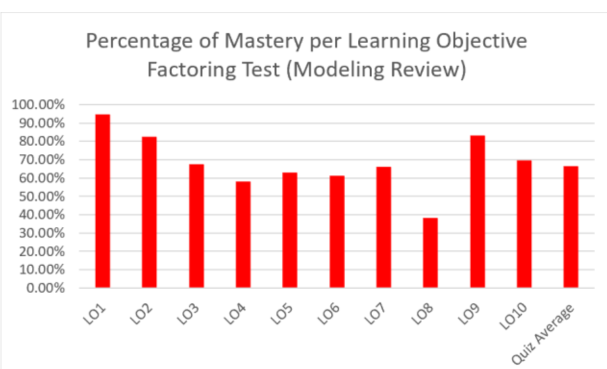

Number of Students Per Mastery Level Quiz 1
8
7
6
5
4
3
2
1
0
0-20%
21-40%
41-60%
61-80%
81-100%
Incomplete

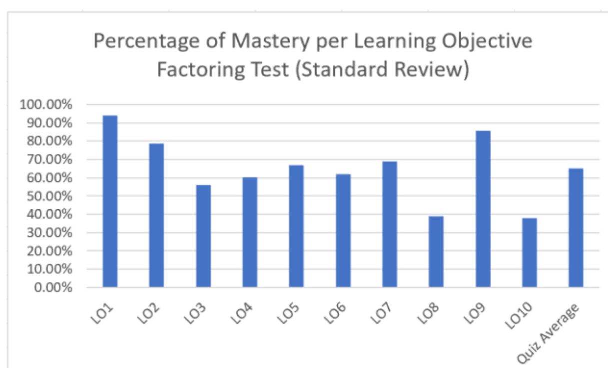

Percentage of Mastery per Learning Objective Quiz 2
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
LO1
LO2
LO3
LO4
LO5
LO6
LO7
LO8
LO9
Quiz Average

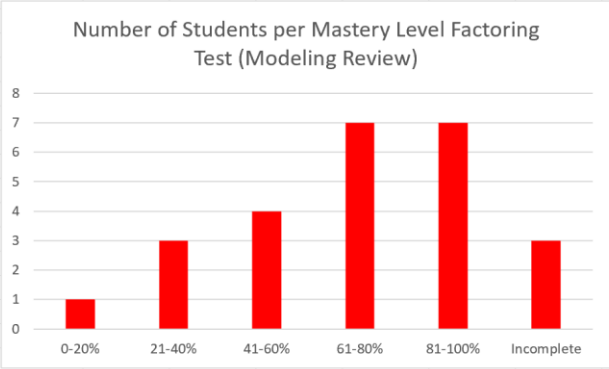

Percentage of Mastery per Learning Objective Quiz 2
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
LO1
LO2
LO3
LO4
LO5
LO6
LO7
LO8
LO9
Quiz Average

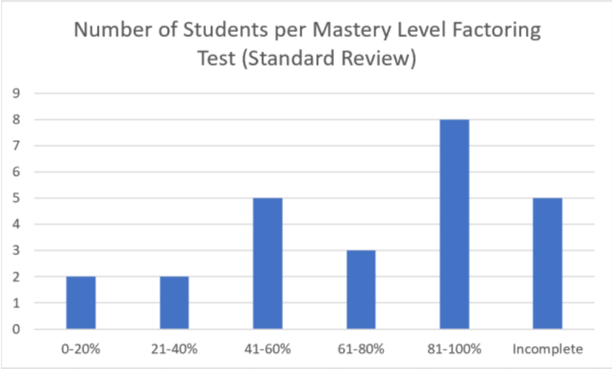

Number of Students per Mastery Level Quiz 2
16
14
12
10
8
6
4
2
0
0-20%
21-40%
41-60%
61-80%
81-100%
Incomplete


Number of Students per Mastery Level Quiz 2
10
9
8
7
6
5
4
3
2
1
0
0-20%
21-40%
41-60%
61-80%
81-100%
Incomplete


Percentage of Mastery per Learning Objective Factoring Test (Modeling Review)
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
LO1
LO2
LO3
LO4
LO5
LO6
LO7
LO8
LO9
LO10
Quiz Average


Percentage of Mastery per Learning Objective Factoring Test (Standard Review)
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
LO1
LO2
LO3
LO4
LO5
LO6
LO7
LO8
LO9
LO10
Quiz Average





In the table below, the increase or decrease within each LO's percentage of mastery from the quiz it first appeared on to Factoring Test (FT) are displayed. For example, LO1 first appeared on Quiz 1 (Q1) and had a percentage of mastery of 84.52% for class one. Students then worked with LO1 again on the FT and reached a mastery level of 94.57%. Students in class one displayed an increase of mastery within LO1 of 10.05%. An "X" in a cell indicates that the given LO does not appear on that assessment.

	LO1	LO2	LO3	LO4	LO5	LO6	LO9
Class One Q1 (Modelling Class)	84.52%	92.86%	62.70%	52.38%	X	X	X
Class One Q2	X	X	X	X	75%	63.66%	84.72%
Class One FT	94.57%	82.61%	67.39%	57.97%	61.23%	66.20%	83.33%
Change in Level of Mastery	▲10.05%	▼10.25%	▲4.69%	▲5.60%	▼11.96%	▼2.43%	▼1.4%
Class Two Q1 (Jeopardy Class)	77.27%	77.65%	59.09%	39.39%	X	X	X
Class Two Q2	X	X	X	X	78.03%	59.96%	83.33%
Class Two FT	94.05%	78.57%	55.95%	60.32%	66.67%	61.90%	85.71%
Change in Level of Mastery	▲16.78%	▲0.92%	▼3.14%	▲2.09%	▼11.36%	▲1.94%	▲2.38%

In class one, appx. 66% of students demonstrated mastery in LO7, appx. 38% in LO8, and appx. 70% in LO10. In class two, appx. 69% of students demonstrated mastery in LO7, appx. 40% in LO8, and appx. 38% in LO10. In class one, eight students reached mastery level (81-100%) on Q1, 14 students reached mastery level on Q2, and seven students reached mastery level on the FT. In class two, seven students reached mastery level on Q1, nine students reached mastery level on Q2, and eight students reached mastery level on the FT. Overall, the class average on Q1 was appx. 76.5% for class one and appx. 65.5% for class two. The class average on Q2 was appx. 85% for class one and appx. 83% for class two. The class average on the FT was appx. 66% for class one and 65% for class two.

Analysis

Generally, the data does not show a significant difference in learning outcomes due to review type used for each class. LO1, factoring monomials, showed a 7% difference of mastery between the two classes, with class two (Jeopardy Review) showing the greater increase in percentage of mastery. LO2, finding the GCF between two monomials, showed an 11% difference of mastery, with class two showing a greater increase in percentage of mastery. LO3, factoring using the GCF Method, showed an 8% difference of mastery between the two classes, with class one (Modelling Review), showing a greater increase. LO4, factor by grouping, showed a 16% difference of mastery, with class two showing a greater increase in percentage of mastery. LO5, factoring using the BC Method, showed little to no difference of mastery between classes. LO6, factoring using the AC Method, showed a 5% difference of mastery, with class two showing a greater increase of percentage of mastery. LO9, determining a, b, and c, in a quadratic expression, showed a 5% difference of mastery, with class two showing a greater increase of percentage of mastery.

LO7, factoring using difference of two squares (a skill not tested on during the checkpoint quizzes), had a difference of 3% of mastery level between the classes, with class two showing the greater percentage of mastery. LO8, factoring using multiple methods, had a difference of 2% of mastery level between the classes, with class two showing the greater percentage of mastery. LO10, determining necessary number of terms to determine ability to use factor by grouping, had a difference of 32% of mastery level between the classes, with class one showing the greater percentage of mastery.

On Q1, one more student in class one reached mastery level compared to class two. On Q2, five more students in class one reached mastery level compared to class two. On the FT, one more student in class one reached mastery level compared to class two. On Q1, the class average was 11% greater in class one compared to class two. On Q2, the class average was 2% greater in class one compared to class two. On the FT, the average was 1% greater in class one compared to class two.

Generally, the data included here requires some explanation about the procedure when calculating results. When a student turned in a blank question/quiz, the results were calculated as zeroes. However, students who attempted problems, but had completely incorrect answers and process also received zeroes. Consequently, blank answers had the potential to sway results in learning objective mastery percentages. Because of this, I chose to also include the number of students per mastery level in order to better demonstrate the results of each class on each assessment.

Based on the data, class two demonstrated greater increases when it came to the specific measured learning objectives. This may be the result of the type of review used with this class.

The more traditional Jeopardy like review gave students more targeted practice time using the mathematical problem-solving skills required for each of the learning objectives, where the modelling task asked students some of these requirements but had a greater focus on their ability to apply these skills. On the other hand, with this same reasoning, class one demonstrated greater levels of mastery across the board, with more students reaching mastery in these classes and their overall quiz results being higher than class two.

Conclusions

Based on the analysis, the results of my research are inconclusive. While class two demonstrated greater growth when it came to individual learning objectives, class one demonstrated greater general understanding of the concepts of the unit. A direct correlation of the review task to the percentage of mastery cannot be made, as most results between the classes are nearly identical (given their graphic representation).

Limitations

If I were to revisit this research, I would need to establish a more consistent means to account for blank answers and uncompleted quizzes and tests. Because of missed school and assignments, there were missing parts of the data set, and likely some inconsistencies in the results. When calculating percentages of mastery, instead of putting an "X" for answers left blank, I put a zero, which curved my data. While a zero would display a given student's understanding of the LO, when calculating results, a blank answer assigned a zero, making the data a mathematical equivalent, when in actuality, the two situations are not the same. A blank answer shows me that a student did not attempt the question, while a zero assigned to shown work displays an attempt but not reached mastery.

When determining which class I wanted to give the modeling task to, I based my decision on previously observed student motivation and engagement levels. Generally, during classroom instruction and work time, class one asked more questions, completed more practice problems, sought help during academic intervention periods, and was overall more engaged during my interactions with them as a class and individually. This learning engagement is more likely to explain their assessment results versus the review used during this time. The modelling task engaged students in class one, and perhaps could increase engagement of students in class two. This requires more classroom time with all students in order to effectively foster the learning environment necessary for these tasks to better take place and be an effective tool for learning and review.

In order to effectively implement MEAs in a classroom, a sufficient time frame is necessary. Due to the complexity and involved practices required within effective MEA implication, time is required for students to think and work through the mathematical applications within real-world scenarios. During my research, even during a review implementation, one 80-minute class period was not enough time to work within the MEA to make the process effective and allow students time to make connections and have the necessary discourse to create meaningful understanding. Curriculum pacing also gets in the way, with the teacher focused on getting through required material, potentially squeezing out time to implement MEAs. Ideally, MEAs should be integrated into curriculum, and not used solely as a supplement to traditional instruction. This would alleviate the potential pacing problem.

Additionally, with my research being conducted in a classroom that is not my own, but instead with a student teacher placement with a cooperating teacher, an establishment of my personal classroom norms did not take place until the second semester. With the first month being one of adjustment to a student teacher, establishing routines (such as regular implantation of modelling tasks within instruction) was difficult due to the short time frame of my time at Rossford. In my future classroom, I envision modelling to be a regular occurrence within my instruction, making its implementation as a review tool to be more applicable and useful.

Implications

Modelling not only that requires students to be thoughtful and use their mathematical discourse skills, but it also requires student understanding and training in routines and procedures. Within my future classroom, I aim to make modelling a regular part of classroom practices. With familiarity of the routines and requirements utilized during any modelling task, students will be able to apply the learned material to a new situation more readily and get to discourse and takeaways more efficiently. This requires training, teacher modelling, classroom discussion and modelling, early in the school year and frequently thereafter. Because this modelling task was the first time students had encountered this type of application, rich mathematical conversation was slim. I spent a good deal of time explaining the steps required of them when modelling. This was a hindrance to their engagement and ability to complete the task. With practice and more frequent exposure, modelling could be measured more effectively as a review tool.

Based on my student teaching experience, I learned the importance of summative assessment as a tool to gauge student understanding. Often, within my time with students, I noticed that if a student was struggling with the given material, there was little time built within my instruction to work with these students. When it came time to review, regardless of the review type being used, these students struggled to participate and engage with the class because they didn’t understand all of the material being reviewed at that summative stage. In order to address this difficulty, a potential implementation within my future classroom would be incremental reviews built into the pacing of my unit. For example, for this particular unit, I could have used a review over the material covered in the checkpoint quizzes. I could have even eliminated the checkpoint quizzes and use that class time to go through a Kahoot over the material to start those conversations about where students might be struggling or making common errors. This type of lower stakes assessment might allow students to attempt more work and create opportunities for them to iron out their own misunderstandings. Additionally, this creates an environment where they can ask the teacher for help and make mistakes in safe way before a summative assessment.

I have also come to understand that review is not one size fits all. I found that when I implemented both reviews for this research, that the activity would have been more effective had I used differentiated review groups. Some kids would have benefitted from a reteaching of material with time to practice with the teacher close by; some needed time simply to practice this material, with a review like Kahoot or Jeopardy game; others were ready for a task like an MEA, and their time would have been spent with peers similarly ready for that learning application. Intentional grouping not only allows students to work at an appropriate level, but also allows the teacher to create an environment where student needs are more efficiently met.

If I choose to implement more regular review, as a part of unit planning and pacing, this type of summative review that traditionally takes place the day before a test, can be reduced or eliminated. More regular low stakes checkpoints in the form of informal reviews, like differentiation stations, eliminates the need for traditional review, and is likely to offer opportunities for student engagement with material. With luck, the traditional review approach of cramming an entire unit of material in a review day will slowly fade.

Conclusion

Based on my literature review, mathematical modelling enriches student learning and deepens mathematical understanding. Though my classroom research results were inconclusive, my time spent modelling with my students revealed this engagement during this learning cycle. Due to the brief time available during a student teaching placement, the norms necessary to best implement and reap the benefits of teaching using modelling were not established. In future research, conducted within my own classroom, the implementation of modelling as a review tool can be closely and effectively studied. Modelling is a complex task that requires trust within a classroom environment and a level of comfort for a student with not only their teacher, but their ability to take risks to work and apply mathematics as a whole. These are the norms I hope to establish before I set out to complete this research again.