Balancing the Equation: Using Socratic Dialogue to Increase Student Engagement and Achievement in a Middle School Mathematics Classroom

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Abstract

Student engagement and achievement are not optimized when using traditional, non-inquiry ways of mathematics learning. This action research study gives insight into the positive relationship that exists between Socratic-type, inquiry-based questions and the level of student achievement and engagement by answering the research question: "How does using Socratic dialogue via inquiry-based questioning as an instructional practice affect engagement and guide academic achievement for middle school mathematics students?" Students were guided through mathematical discussions by teacher-led Socratic dialogue-type questions during initial unit introduction. Results of this action-research study support the positive relationship between student achievement and engagement, spotlighting the importance of dialogue within a math classroom as a call to action for all teachers. Continued scholarly investigation will help educators implement new pedagogies that will provide students with experiences that improve their learning environments and can help bridge the learning gaps often visible in mathematics.

Keywords: student engagement, academic achievement, Socratic dialogue, inquiry-based questions, middle school mathematics

Introduction

As teachers, we have the responsibility to empower our students so that each of them has the opportunity to grow as individuals. Teaching *how to learn* is a focus that is beyond traditional objectives of presenting material at the front of our classes. Traditional, non-inquiry way of mathematics learning in the classroom is creating barriers to student engagement and achievement. Simply stated, school makes math boring, and bored students do not learn successfully (Greenes, 2009). With traditional approaches of lecture and rote memorization of facts and formulas, we are squandering opportunities to inspire and motivate our students toward the beauty of mathematical thinking. Many math students and teachers have the misconception that solving math problems requires memorization of formulas and applying specific procedures to find the answers as opposed to gaining a deep understanding of the problem and why formulas and steps lead to a solution. Additionally, the lack of student collaboration within a mathematics classroom may be contributing to the student belief that mathematics is meant to be done individually, isolating students to a solitary struggle. This underlying dilemma has led me to reflect on my teaching practice and ask: *How does using Socratic dialogues via inquiry-based questioning as an instructional practice affect engagement and guide academic achievement for middle school mathematics students?*

The purpose of this action research study is to give insight into the relationship that exists between Socratic dialogue and inquiry-based questions as instructional practices in middle school mathematics with the level of student engagement in class and unit achievement on summative assessments.

Context

The study took place at an independent, co-educational Pre-K through 12th-grade college preparatory school in Broward County, FL with a maximum enrollment of 1,650 students. As a middle school mathematics teacher, I am empowered to set my teaching practice up how I choose and to enrich the curriculum as I feel best suits each of my students. The school's guiding philosophy is to be ambitious while promoting individualized learning, creativity, and critical thinking. Having taught middle school math in three other local independent schools for 15 years prior, I chose to continue my profession here because of its guiding philosophy.

Teaching Philosophy

As one of the five middle school pre-algebra and Algebra 1 teachers, my teaching assignment includes three classes of pre-algebra and two of Algebra 1. Most of my pre-algebra classes have about 18 students of mixed sixth, seventh, and eighth graders. The joyful interaction and discussions I have with my students are aimed to motivate them academically while creating a positive emotional connection to the subject matter. It is my belief that by taking the same approach in the classroom as a sports coach does on the field, meaningful learning occurs. Traditional instructional practices have separated the meaning behind *teachin*g and *coaching*. But it is through the approach that a coach takes on an athletic field that I truly reach my students. Having coached junior varsity and varsity athletic teams, while also coaching academic math competition teams, I have come to realize that the pedagogy behind both is equally successful in my secondary mathematics classroom. Focusing on my students' unique strengths, individualized scaffolding, or modeling of problem-solving strategies during collaborative classroom discussions, helps students learn just as well in the classroom as on the field. Within the walls of my classroom, I take the role of not just a teacher but more of their learning coach, and my students even address me as Coach.

Through a cognitive constructivist lens, my teaching framework is marked by maintaining constant synergy between cognitive approaches to instruction in a joyful classroom by providing experiences and contexts that encourage active learning in a student-centered class. This is visible in exercises at the beginning of each unit where students are called to reflect on the title of the unit and try to elaborate on everything that they previously know about the words mentioned to create language meaning prior to making mathematical connections. Through this type of exercise, students draw connections to their prior knowledge of each of these terms and construct their belief of the mathematical application. I try to advocate for students to use their own judgment so the construction of new concepts can then be built upon, reaching a higher level of knowledge and understanding. In my classroom, learning is facilitated by collaboration and mathematical discussions prompted and guided by visible thinking routines to organize the progress of students' connections with the material presented. Much of the pre-algebra curriculum consists of material students have been introduced to in previous years. In this course, the meaningful foundations of algebraic thinking and reasoning are created. Throughout my 18 years of teaching, I have noticed that as I moved away from a traditional teaching style and towards learning that occurs through discussions, students were more engaged and demonstrated greater mastery of the concepts. Yearly self-reflection has not only improved my teaching practice but has led me to understand that embracing social interactions and dialogue within the classroom through Socratic-type of questions leads to students' creation of meaning and strengthens achievement.

Literature Review

The Mathematical Association of America published an essay by renowned mathematician Paul Lockhart (2019) where he describes the importance of learning mathematics through inquiry versus just working towards answers:

> By concentrating on what, and leaving out why, mathematics is reduced to an empty shell. The art is not in the 'truth' but in the explanation, the argument. It is the argument itself which gives the truth its context and determines what is really being said and meant. Mathematics is the art of explanation. (p. 5)

During the 1980s, The National Council for Teachers of Mathematics (NCTM) initiated a reform of school mathematics towards a pedagogy that "challenged the student's role as passive listener who memorized facts and worked only on assigned problems" (Gurung et al., 2009, p. 262). Gurung et al. (2009) also discussed a study conducted by Eley and Meyer (2004) where through an analysis of 400 students using the Mathematics Study Process Inventory (MSPI), it was revealed that students struggling in mathematics used traditional approaches in math like blindly using formulas to solve problems. A similar study by Kloosterman (1995) as discussed in Gurung et al. (2009), found that the majority of students interviewed believed that mathematics required the following of specific steps. Women in Kloosterman's (1995) study who disagreed with this belief were the students most successful in the math course. It is for the above reasons that Gurung et al. (2009) urge mathematics educators to accept that "any signature pedagogy in mathematics must include instructional and assessment techniques that address conceptual knowledge and promote perseverance in problem-solving situations" (p. 267). Conducting further research to promote growth of the Scholarship of Teaching and Learning (SoTL) in mathematics education will draw attention to the importance of understanding that students' learning is affected by the instructional approaches used.

Inquiry-Based Learning in the Mathematics Classroom

Mathematics is a subject derived from human interaction, it is "a language of human action" (Confrey, 1990, p. 109). Concepts from learning to count, performing operations and solving for unknown quantities, to graphing functions, statistically analyzing data or even creating mathematical models that explain economic or physical behavior, are all based on the foundational piece that mathematics is a language reflecting activity where internal thought processes must be carried out in order to represent abstract ideas (Confrey, 1990). Beginning at around age 12 and through adulthood, learners are in what Piaget described as the *formal operational stage* (Piaget & Coltman, 1977; Berk, 2007). The development of abstract thought patterns provides students at this stage the ability to make deductive inferences in mathematics, connecting mathematical concepts to the real-world (Ojose, 2008; Greenes, 2009). Personal growth during these formative years can be accelerated by the provision of critical inquiry where students are led to discover concepts through investigation. Learning environments that encourage students to question, reason, and reflect provide optimal opportunities for students to better understand their thinking. This lends to students' increased engagement and achievement where subject knowledge grows optimally (Piaget & Coltman, 1977). Traditional mathematics classrooms where students are provided with information rather than knowledge, simply are conditioning learners to access the information rather than process and personalize it. Students are taught to access information quickly rather than comprehend it and internalize it. Direct instruction does not provide the inquiry and foundation needed for students to develop their higher-order cognitive skills (Abdi, 2014; Confrey, 1990).

Taylor and Bilbrey's (2012) research on the effectiveness of inquiry-based instruction for fifth-grade science and mathematics focused on the transition of curriculum from traditional-based to inquiry-based instruction. Researchers statistically analyzed the mathematics and science standardized test scores to identify trends that occurred in the three years before Alabama Math Science and Technology Inquiry (AMSTI) implementation and the three years following AMSTI implementation (Taylor & Bilbrey, 2012). The researchers in this study based their theoretical framework on Vygotsky's and Dewey's contributions to constructivist learning theory where the role of the teacher is to lead students' learning. The difference between teacher-directed instruction and inquiry-based learning is that students learning through inquiry "…construct personal interpretation of knowledge based on their previous experience and application of knowledge in a relevant context," (Taylor &

Bilbrey, 2012, p. 6). Guiding instruction by questions and inquiry provides a "…non-passive presence which was requested through the use of the inquiry-based model for guided questions…in both an effective and motivated manner" (Taylor & Bilbrey, 2012, p. 7). Furthermore, it was found that inquiry-based mathematics instruction is even "effective in increasing student mathematics achievement…for certain student subgroups, particularly black students" (Taylor & Bilbrey, 2012, p. 12).

Student-centered instruction of mathematics such as the Modified Moore Method (MMM), named after the mathematician R. L. Moore, focuses learning on student discovery of mathematical principles (Bailey et al., 2012). Contrary to the traditional approach of instruction, where mathematics is taught with routine and well-defined rules and procedures, instructors who use the MMM in their classes structure learning experiences around Socratic-style questions as the vehicle of student learning (Bailey et al., 2012). The Moore method has been associated with discovery-based, inquiry-based, student-centered, Socratic, and constructivist approaches to learning. In essence, it is a Socratic method of teaching encouraging students to solve problems using their creativity and analysis (Bailey et al., 2012).

In a study conducted by Bailey et al. (2012), pre-calculus was taught in two sections, the treatment section (11 males, 27 females) where students were taught by MMM, and two control traditional lecture sections (control group 1 had 16 males and 23 females, and control group 2 had 16 males and 22 females). The researchers' aim was to study the difference in attitudes, beliefs, and self-efficacy of pre-calculus students taught by MMM versus the traditional lecture approach. After confirming that all groups had similar pre-research baseline scores of attitudes and beliefs (ATT) at the beginning of the semester, the control and treatment groups were taught using their respective traditional and MMM approaches. Statistical analysis of the data suggested that students with low ATT scores corresponded with traditional lecture instruction and those students scored worse on the final exam compared to the scores of those in the MMM group (Bailey et al., 2012).

Another study published by the National Council of Teachers of Mathematics (NCTM) focusing on how student learning and attitudes are affected by inquiry-based learning (IBL) courses conducted by Laursen et al. (2014), found that the perceived gender gap that exists in mathematics learning can be bridged using IBL. NCTM reported that women's "cognitive and effective gains were statistically identical to those of men, and their collaborative gains were higher," which the researchers insist "suggest that learning gains reported by women in non-IBL classes reflect their weaker sense of mastery, rather than a real gap in performance" (Laursen et al., 2014, p. 412). Comparing how time is utilized in classrooms, the researchers found that students in traditional courses spend 87% of class time listening to their instructors talk while over 60% of IBL class time is spent doing and discussing mathematics through student-centered activities (Laursen et al., 2014). This data suggests that IBL approaches to mathematics instruction "leveled the playing field by offering learning experiences of equal benefit to men and women, while non-IBL courses were more discouraging and less effective for women in particular" (Laursen et al., 2014, p. 412).

Applying constructivism to teaching through IBL methods demonstrates a positive impact on student learning and motivation even when seeing it through the lens of a topic-specific mathematical principle such as circle theorem (Mensah-Wonky, & Adu, 2016). Using pre- and post-tests to assess students' understanding of circle theorems along with a questionnaire for measuring the students' perception of motivation, Mensah-Wonky and Adu (2016) discovered that students in the IBL group achieved better results than those in the traditional instruction group. Statistical analysis revealed a significant difference for these students, indicating "tremendous improvement in the understanding…in circle theorems in plane geometry" (Mensah-Wonky & Adu, 2016, p. 70). Additionally, self-perceived motivation among students in the IBL group was higher than for those in the traditional instruction group. The authors concluded that students taught with IBL "perceive their mathematics learning environment as high in motivation" while those in traditional groups perceived low motivation (Mensah-Wonky, & Adu, 2016, p. 70).

Within their study, Mensah-Wonky and Adu (2016) described traditional methods of instruction as passive where students are "made to act as spectators rather than partakers in the learning process," which "does not enhance critical thinking and collaborative problem-solving…" (p. 62). An effective IBL classroom is one where teachers use a curriculum to develop open-ended questions, leading students to their own questions, guiding their exploration into activities that activate prior knowledge and increase student engagement (Crombie 2009 in Wonky & Adu, 2016, p. 65). The results of these and many other studies solidify the importance that mathematics teachers must have a solid pedagogy so as to guide students' view of their world. Teaching *how to learn* is a focus that is beyond the traditional objectives of presenting material at the front of a class as it uses an inquiry-based approach guided by questions and discussions which activate prior knowledge and build a solid mathematical foundation while increasing student engagement and achievement.

Inquiry-Based Learning Increases Achievement and Bridges Learning Gaps

According to the National Research Council (1996), inquiry-based learning (IBL) includes teaching through questioning, observations, and creating explanations. Dewey (1938) described IBL as a method of teaching where the educators provide the knowledge of the subject matter that leads to activities where students drive their own learning. Several studies have been done in recent years comparing the difference that IBL has on student achievement, engagement, and affect.

In an eight-week study conducted by Abdi (2014), 20 fifth-grade students were placed into a control group where traditional instruction was implemented and the other 20 were placed in the experimental group utilizing the IBL method. Abdi (2014) found a statistically significant positive effect for IBL over the traditional teaching approach. Aslan (2019) conducted research where students were randomly grouped into two experimental groups and one control group. Students in the control group were set in traditional learning environments with direct teacher instruction while those in experimental group 1 were taught by what the researcher named "argumentation-based teaching," where the aim was to provide students with knowledge that was based on inquiry by asking questions, making claims, and supporting their arguments. Those in experimental group 2 were taught by "scenario-based learning" and presented with different scenarios to provide meaningful learning through experiential and hands-on approaches (Aslan, 2019). During the seven-week study, learning was organized by the implementation of a pre-test, instruction in the specified method, and a post-test to measure learning. Within each individual group, learning was demonstrated to have occurred using each of the instructional methods. Across all three groups, however, the highest score belonged to the argumentation-based teaching group (Aslan, 2019). Utilizing a Socratic approach of leading discussions through inquiry-based questions develops a deeper connection of meaning to the knowledge students acquire.

Yesildag-Hasancebi and Gunel (2013) launched a study on the impact that argumentation-based inquiry approach (ABI) had on low-achieving and socioeconomically disadvantaged students. In their quasi-experimental research, 55 students in eighth grade residing in a low socioeconomic neighborhood were randomly assigned to a treatment or control class. Using a pre- and post-test design, students in the experimental (ABI) group demonstrated higher scores. Furthermore, the researchers found that students' ability to reason and develop arguments was significantly correlated with higher test scores. Most significantly, race and gender learning gaps can be closed through the use of "inquiry learning environments" that use ABI (Geier et al., 2008). In a similar research focus, Acar (2015) studied 26 students in eighth grade from two schools in a low socioeconomic region and 31 students in eighth grade from a school in a high socioeconomic region. During the four months of the research study, pre- and post-tests were given to assess students' reasoning and knowledge looking for differences guided by ABI and traditional approaches to instruction. As defined by the researchers in this study, ABI should be thought of as “a constructivist teaching method, because student discussion and reasoning are at the core” (Acar, 2015, p. 1). According to statistical analysis, students in the ABI group developed their scientific reasoning at a higher rate than those with traditional instruction. Taking all of the different analyses done within this study, the results signify that IBL focused on discussion and questioning is not only helpful in enhancing students’ scientific reasoning but also closes “conceptual knowledge and scientific reasoning gaps between concrete and formal reasoning groups” (Acar, 2015, p. 34). This student-centered, discussion-based approach to instruction even bridges learning gaps that exist for disadvantaged students.

Focusing on inductive learning through Socratic dialogues and inquiry-based questioning moves math education away from the misconceptions that promote traditional lecture-based, rule-following instruction. Innovative uses of technology and using Socratic dialogue and discovery are all approaches that can move math instruction toward the direction of increased student engagement and achievement (Gurung et al., 2009). Constant collaboration that inquiry-based Socratic dialogues create helps meet the key components of learning such as communication and interaction, which are essential parts of mathematics education (Gurung et al., 2009). An emerging signature pedagogy in mathematics includes using cooperative learning techniques, of which research discusses the positive effects on student achievement, persistence, and attitudes (Springer et al., 1999). This suggests that “greater time spent working in groups leads to more favorable attitudes among students in general” (Springer et al., 1999, p. 269). Engaging in Socratic questioning during the introduction and exploration of new concepts in mathematics initiates student learning and engagement (Curtis, 2019). As Posner (2004) elaborates on Socratic dialogue, teaching abstract and complex ideas “without appearing to tell (his) students anything,” remains “the prototype of great teaching” (p. 61). The purpose of this action research study is to give insight into the relationship that exists between Socratic dialogue as an instructional practice and the level of student engagement and unit achievement on summative assessments.

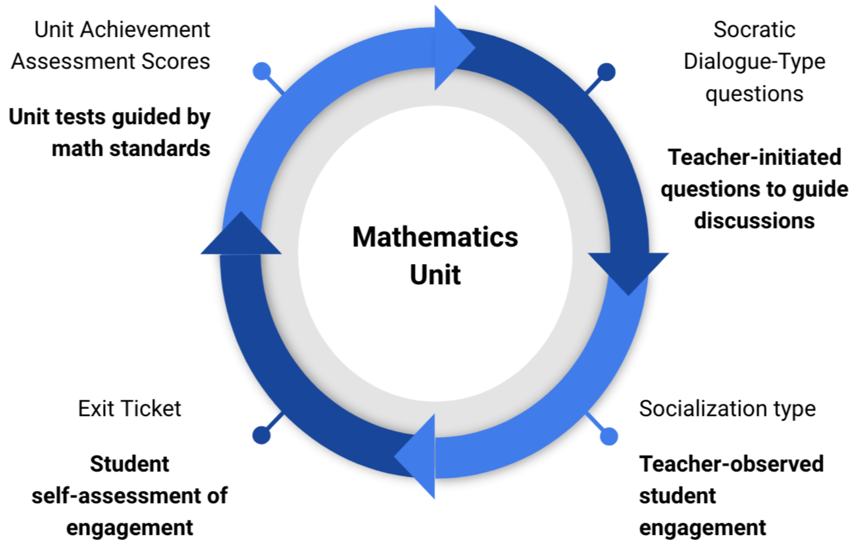
Methodology

This action research study was designed to explore teacher-student interactions and student achievement during the first trimester of a middle school mathematics course that ran for approximately 12 weeks. Classes were formed at the beginning of the school year by administrators and included a pre-algebra middle school class of 12 students in sixth and seventh grades ranging in ages from 11 to 13. All students within the assigned class were included and used as a sample of middle school mathematics students. The regular class schedule runs what the school calls a “fusion schedule.” Middle school students meet all seven class periods on Mondays, Thursdays, and Fridays, and “fusion” days are held on Tuesdays and Wednesdays, with odd period classes meeting on Tuesdays for 90 minutes and even period classes meeting for 90 minutes on Wednesdays. This allows all subjects to meet for 90 minutes once a week for the purpose of diving deeper into material with opportunities to work on subject-specific projects or a larger horizontal alignment of curriculum across the subjects.

Study Design

The action research study occurred weekly during fusion class periods for the first trimester where the class was structured around discussion of mathematics topics within the units of the planned curriculum map. Students were guided through mathematical discussions by teacher-led Socratic dialogue-type questions as the four different units were first introduced: Unit 1- Operations with integers (09/04/19), Unit 2- Solving two-step equations (09/18/19), Unit 3- Solving multi-step equations (10/02/19) and Unit 4- Solving inequalities (10/23/19). Video and voice recordings of lessons allowed for the collection of qualitative and quantitative data. A research journal was kept for teacher reflections.

Figure 1. *Structure of Class Discussions*



Analysis of Data

At the conclusion of each of the four units, data was collected using Table 1 by tallying the quantity of Socratic dialogue-type questions (QtySocQst) that the teacher posed during the lesson. The number of times students engaged with the lesson was tallied based on the socialization type demonstrated (SocType) labeled as follows: answering question with or without raising hand, posing question with or without raising hand, writing notes or working out math problem, visual cue of engagement including raising hand to get teacher attention.

Table 1. *Socratic Dialogue Questions*

Clarifying questions	Perspectives
• What is another way you could solve that problem? • How does ...relate to ...? • Could you give me an example of ...? • Could you explain that further? • How does this relate to what you learned about...?	• What is another way to approach this problem? • Could you solve this problem if you assumed...? • Would you explain why you used this ...? • How are the formulas for ... and ... similar? How are they different?
Examining reasons	Questions about the question
• What would be an example of that principle? • What other information do you need to know to solve this problem? • Does the formula you learned previously apply to this problem? • What is another example of when you would apply this rule/formula?	• How can you prove that answer? • Can you break this problem down into simpler components? • Do you have all of the facts you need to solve this problem? • What is the main question for which you need to find the answer? • Does this question provide additional information that changes your answer to the previous problem?
Challenging assumptions	Exploring implications and consequences
• What assumptions are you making to solve the problem? • Could you solve the problem with different assumptions? • Does this formula always apply or are there circumstances that require a different approach or formula? • Is a ...always a ...? • Why do you think… is …?	• What is an alternative way to solve this problem? • What effect would changing... have on …? • What generalizations can you make about ...?

Students were provided with a self-rated Math Discussion Exit Ticket (Appendix 1) asking students to select how engaged in the lesson they felt using a linear rating scale between 1 to 5 (1 being lowest and 5 being highest). Lastly, the individual students' scores were gathered on each of the unit summative assessments which were teacher-created and in alignment with National Council of Teachers of Mathematics (NCTM) grades 6-8 standards guided by the school's Mathematics Grades 6-8 Targeted Standards (Appendix 2). The students completed their assessments in class at the completion of each unit on the following dates: Unit 1- Operations with integers (09/16/19), Unit 2- Solving two-step equations (10/07/19), Unit 3- Solving multi-step equations (10/22/19) and Unit 4- Solving inequalities (11/06/19).

Results

Socratic Questions Asked by Teacher

Looking at Table 2, the teacher asked an average of 21 Socratic-type questions (QtySocQst) in Unit 1, 24.17 questions in Unit 2, 20.83 questions in Unit 3, and 20.5 questions in Unit 4. In my teacher journal, I wrote "I wonder if having less Socratic questions for this unit is going to impact their unit test scores" (Teacher journal, Unit 1, 09/04/19).

Table 2. *Quantity of Socratic Questions Asked by Teacher (QtySocQst)*

	Clarifying	Challenging assumptions	Examining reasons	Perspectives	Exploring implications and consequences	Question about the questions	Mean QtySocQst
U1- Operations w/ integers	42	10	16	24	10.00	24.00	21.00
U2- Solving two-step equations	47	18	17	23	14.00	26.00	24.17
U3- Solving multi-step equations	35	16	15	21	16.00	22.00	20.83
U4- Solving inequalities	44	12	15	16	17.00	19.00	20.50

Student Engagement

Socialization type (SocType) results are shown in Table 3. The overall unit mean results show that during Unit 3 students were the most actively engaged with the lesson an average of 88.25 times. The next highest socialization occurred in Unit 2 with an overall unit mean of 87.75 times that all students engaged with the lesson. During Unit 1, students engaged an average of 79.5 times. Unit 4 was close to the same amount of student engagement with a mean of 79.25.

Table 3. *Student Engagement (SocType)*

Socialization type (SocType)	Tallied results: Unit 1	Tallied Results: Unit 2	Tallied results: Unit 3	Tallied results: Unit 4
Answering question (with or without raising hand)	54.00	161.00	135.00	115.00
Posing question (with or without raising hand)	52.00	58.00	66.00	44.00
Writing notes or working math problem out	30.00	41.00	51.00	62.00
Visual cue of engagement	82.00	91.00	101.00	96.00
Overall unit mean score	79.50	87.75	88.25	79.25

As noted in the teacher journal during the class discussion in Unit 2 the students were visibly more engaged, "it felt as if students more often were answering my questions and visually to me seemed to be more attentive- writing down more notes, raising their hands or just giving me cues that they were thinking" (Teacher journal, 09/18/19). The Socratic-type questions during Unit 2 were not as structured as they had been in the first unit as noted from the teacher journal on that day: "let the students guide my questions more than me trying to guide their thinking with questions" (Teacher journal, 09/18/19).

Students were surveyed on how engaged in the lesson they felt by a self-assessment exit ticket (ExitTkt) using a linear rating scale of 1 to 5 (1 being lowest and 5 being highest). The Google Form collected the data from the linear questions in a spreadsheet summarized in Table 4. Overall, Unit 3 was the highest scored by the students as they averaged 4.17 out of 5 on how engaged they felt in the lesson. Averaging a close 4.13 was Unit 2, followed by Unit 1 at 4.07, and Unit 4 with an average of 3.74.

Table 3. *Exit Ticket Overall Unit Means (ExitTkt)*

Exit ticket linear questions	Average score: Unit 1	Average score: Unit 2	Average score: Unit 3	Average score: Unit 4	ExitTick mean score
How engaged did you feel in the class discussion today?	3.92	4.00	3.94	4.00	3.97
Do you feel you could apply what you learned in real life?	4.33	3.94	4.23	3.24	3.94
Do you think this way of learning math is fun? (by talking and asking questions)	3.96	4.44	4.33	3.99	4.18
Overall unit mean score	4.07	4.13	4.17	3.74	4.03

Student Achievement Scores

Students completed a summative assessment at the end of each unit. The percent correct scored by each student was gathered and is displayed in Table 5. The unit average scores from highest to lowest show Unit 2 having the highest percent average of 95.9%, followed by Unit 4 with a percent average of 94.7%, Unit 3 at 93.9%, and Unit 1 at 93.5%.

Table 5. *Student Unit Assessment Scores (Achv/Scor)*

Student	Unit 1: Operations w/ integers	Unit 2: Solving two-step equations	Unit 3: Solving multi-step equations	Unit 4: Solving inequalities	Student unit assessment average
1	90	100	91	97	94.50
2	88	98	94	90	92.50
3	100	100	98	100	99.50
4	96	100	100	96	98.00
5	92	93	68	88	85.25
6	92	91	94	83	90.00
7	90	98	95	100	95.75
8	92	80	97	90	89.75
9	100	100	100	100	100.00
10	98	100	99	96	98.25
11	90	91	97	98	94.00
12	94	100	94	98	96.50
UnitAvg score	93.50	95.90	93.90	94.70	94.50

Conclusions

Through the data collected, it is possible to visualize that achievement (AchvScor) is positively affected by the quantity of Socratic-type questions asked by the teacher (QtySocQst) and the level of student engagement as seen by the quantity of socialization the students exhibited (SocType) was juxtaposed with their self-assessment on engagement through the exit tickets (ExitTkt).

Socratic Questions and Student Engagement

Although this was a small sample and could yield no causal relationship, the data suggests that when the quantity of Socratic questions asked by the teacher increases, the level of engagement also increases. Through analysis of SocType results, interactions were further broken down by gender, as seen in Table 6. Females and males were equally engaged at 44.125 times during Unit 3. During Unit 2, the five females engaged an average of 44.25 times and the seven males 43.5 times. Unit 1 level of engagement showed females averaged 40.5 times interacting with the lesson and males an average level of socialization was 39 times. Unit 4 student engagement of 79.25 consisted of the females' mean of 41 and males' 38.25.

Table 6. *Socialization by Gender (SocGndr)*

Unit	Unit 1	Unit 2	Unit 3	Unit 4
Females (5)	40.50	44.25	44.13	41.00
Males (7)	39.00	43.50	44.13	38.25

Further analysis of the student exit ticket self-assessing their level of engagement resulted in Table 7 where it is seen that in Unit 2, females self-assessed on average at 4.6 out of 5.00, closely followed by Unit 3 at 4.59, Unit 1 at 4.28, and Unit 4 at 3.92. Males self-assessed the highest on Unit 1 at 3.86, Unit 3 at 3.75 out of 5, Unit 2 at 3.66, and Unit 4 at 3.56 out of 4.00. Overall, the mean by gender for females was 4.35 out of 5.00 and males' self-rating was 3.71 out of 5.00.

Table 7. *Exit Ticket Self-Assessment by Gender (ExTktGndr)*

Gender	Unit 1	Unit 2	Unit 3	Unit 4	Mean by gender
Females	4.28	4.60	4.59	3.92	4.35
Males	3.86	3.66	3.75	3.56	3.71
Overall unit means	4.07	4.13	4.17	3.74	4.03

Gender, Achievement and Engagement

Results of the unit summative assessments for each student were gathered and the mean score per unit in the class was calculated. Gender differences were also considered by averaging female and male scores separately. An unintended finding in the data led to a deeper analysis of the data by gender. After gathering the data, an additional table was created to organize the students' unit assessment scores by gender in Table 8. Females scored an overall average of 95.95%, while males' mean score was 93.46%. Breaking it down by units, females scored highest in Unit 2 with a 97.4%, followed by Unit 3 at 96.8%, Unit 4 at 96.8% and Unit 1 at 92.8%. Males scored the highest average on Unit 2 at 94.86%, Unit 1 scoring 94.00%, Unit 4 at 93.14%, and Unit 3 at 91.86%.

Table 8. *Student Unit Assessment Scores by Gender (AchvGndr)*

Unit	Females	Males
Unit 1: Operations w/ integers	92.80	94.00
Unit 2: Solving two-step equations	97.20	94.86
Unit 3: Solving multi-step equation	96.80	91.86
Unit 4: Solving Inequalities	96.80	93.14
Student Unit Assessment Average	95.90	93.47

As this action research study was being conducted, it was evident that the females in the class were achieving at a higher level than the males, and that the females' self-rating on the level of engagement was also higher. The triangulation of this data led to the discovery that there was a positive relationship between the student unit assessment scores by gender, exit ticket self-assessment by gender, and level of socialization by gender. The unintended finding was not just that the females' overall unit assessment score averages were higher than the males, but that in Unit 2 which had the highest average number of Socratic-type questions asked by the teacher also had the highest assessment score average for both males and females and also held the highest self-assessment of engagement by females in their exit ticket at 4.6, while also having the highest level of socialization by females at 44.25.

A simple bivariate correlation of the data collected in the class was used to examine the interrelationships of the variables. As shown in Table 9 there is a strong positive correlation of 0.818 between QtySocQst and AchvScor. Looking at the QtySocQst and SocType, there is a strong positive correlation of 0.560 as well as between QtySocQst and ExitTkt with a moderately strong value of 0.442. However, in reviewing the significance of possible correlations, we can see that due to the small sample size and only four units of study, the correlation is not statistically significant, and we can conclude there is not enough evidence that exists to say this would be significant across the entire population. It does, however, warrant more research in this area to have stronger findings.

Table 9. *Correlations*

		AcvhScor	QtySocQst	SocType	ExtTkt
Pearson correlation	AcvhScor	1.000	0.818	0.395	-0.067
	QtySocQst	0.818	1.000	0.560	0.442
	SocType	0.395	0.560	1.000	0.738
	ExitTkt	-0.067	0.442	0.738	1.000
Sig. (1-tailed)	AcvhScor		0.091	0.303	0.466
	QtySocQst	0.091		0.220	0.279
	SocType	0.303	0.220		0.131
	ExitTkt	0.466	0.279	0.131	
N	AcvhScor	4	4	4	
	QtySocQst	4	4	4	
	SocType	4	4	4	
	ExitTkt	4	4	4	

Descriptive statistics for the variables are shown in Table 10. This data shows that the mean of the QtySocQst asked by the teacher was 21.63 (*SD* = 1.478*)*, the SocType displayed by students and documented by teacher average was 83.69 (*SD* = 4.317*)*, mean of the ExitTick self-assessment by students was 4.03 (*SD* = 0.184*)*, and the UnitAvg for unit assessments was 94.50 (*SD* = 0.919*).*

Table 10. *Descriptive Statistics*

Variable	Mean	SD
QtySocQst	21.63	1.478
SocType	83.69	4.317
ExitTick	4.03	0.184
UnitAvg	94.50	0.919

Implications

Based on the findings obtained in this action research study, we can see that although the sample size was small, there was a strong enough positive relationship to call for more research in this area and support the findings from researchers who believe that the gender gap in the subject of mathematics can be eliminated by using inquiry-based learning tools such as leading mathematical discussions through Socratic-type questions (Laursen et al., 2014) (Acar, 2015). In recent studies, the idea that more males end up in STEM fields because of their higher mathematical abilities has been dismissed. The continuing stereotype, however, that females lack mathematical ability, calls for more opportunities to bridge the perceived gender differences in mathematical performance. Particularly important is that parents and teachers often overrate boys' ability relative to girls' (Lindberg et al., 2010). It is not the academic ability that is different between males and females, it is their self-perceived ability. Ganley and Lubienski (2016) explain in their NCTM article regarding current findings on gender differences in math that research consistently shows that females' lower confidence and higher anxiety than males is the main contributing factor to the lower math achievement they experience. These differences, however, can be eliminated when educators are committed to reframing math pedagogy toward providing opportunities for students to think flexibly and question deeply.

In response to the research question, this action research study demonstrated a positive relationship between the use of Socratic dialogue and inquiry-based questions as instructional practices with the level of student engagement visible to the teacher, the self-assessment of engagement by students, and the students' performance on their unit summative assessments. Furthermore, the traditional approach to teaching mathematics as a lecture on new content is a teacher-centered pedagogy that does not lead students in the mathematical reasoning that is necessary to solve problems. Educators should work on developing questions that will guide learning and engage students in order to extend their understanding while also helping them make new mathematical connections. As Ernie et al. (2009) discuss in their chapter on mathematical reasoning, it is imperative for the teaching of mathematics to include techniques that promote problem-solving. Further research in regards to the scholarship of teaching and learning (SoTL) in mathematics is necessary to "alter the belief that mathematics consists of isolated facts used to solve problems quickly…" (Gurung et al., 2009, p. 267). Substantial research exists in the field of cooperative learning and findings confirm that academic achievement increases when students have more favorable attitudes about the class (Gurung et al., 2009). Additionally, the misconception that teachers should be the "sage on the stage" and the center of traditional mathematics classrooms, can be corrected by fostering students' learning through the way the content is presented. Perhaps the most dominant belief by math students is that mathematical ability is genetic and innate. This misconception is perpetuated by society and since math gets progressively more complex throughout the years, it is our educational responsibility to ignite students' effectiveness in mathematical communication and their critical thinking.

Mathematical reasoning is relevant and necessary for true comprehension. Through this study, I learned that one of the most influential methods to impact students is through teacher use of action research. As I observed my students and gathered data during my research, I found myself more vested in their outcomes than I felt with the other classes I was not studying. Although I taught my other classes similarly, I found that I was much more energetic about seeing the studied classes' performance and engagement. I wonder if this also had something to do with their higher level of achievement as I compared them "off the record" to the other classes I taught but did not study this semester. Within the field of middle school mathematics, I feel that action research should be a continuous theme and daily practice for all teachers. Just as this action research study brought to light the importance of dialogue within a math classroom, it is also a call to action for all teachers to actively work on their practice and expand their own knowledge of their students' learning. Additional research in teaching and learning mathematics must center around the real-world connections that inquiry-based learning guided by Socratic-type questions and dialogue can provide. Continued scholarly investigation will help educators implement new pedagogies that will provide students with experiences that not only improve their learning environments, but most importantly can help bridge the perceived learning gaps that have often been visible in mathematics (Laursen et al., 2014). Research has demonstrated that the gender gap in mathematics can be reversed in societies with more gender equality (Lindberg et al., 2010). Furthermore, through this action research process, I discovered it is important to anticipate unintended findings that will create a need to dive deeper into the topic of guiding math learning through questions and discussions. Fostering greater engagement in math learning can be achieved not only by a collaborative environment but also through the development of authentic experiences that only deep conversation and questioning can provide.

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Appendix A

Math Discussion Exit Ticket

How engaged did you feel in the class discussion today? *

	1	2	3	4	5	
Not engaged- very bored	○	○	○	○	○	Very engaged! Time flew by today!

Do you feel you could apply what you learned in real life? *

	1	2	3	4	5	
I don't think so	○	○	○	○	○	Yes. I feel I can use it in real life!

What was the best KIND of question you heard in math class today? *

- ○ Clarifying questions
- ○ Challenging assumptions:
- ○ Examining reasons
- ○ Perspectives
- ○ Exploring implications and consequences
- ○ Questions about the question

Do you think this way of learning math is fun? (by talking and asking questions) *

	1	2	3	4	5	
no. I like to sit and listen to the teacher lecture while I just take notes.	○	○	○	○	○	YES! I feel it is fun to learn by talking and asking questions.

Appendix B

Mathematics Grades 6–8 Targeted Standards

School standards	NCTM Standards
<u>Modes of Inquiry in Mathematics</u> ★ 16.6-8.MAT.MI.001 Student models and demonstrates methods of solving equations, inequalities, and/or situations involving variable quantities ★ 16.6-8.MAT.MI.002 Student formulates extensions and generalization in mathematical context ★ 16.6-8.MAT.MI.003 Student constructs and applies models to real world situations using expressions, statements, and/or matrices ★ 16.6-8.MAT.MI.004 Student is able to construct and understand tables, graphs, and/or apply concepts involving Algebraic Geometry **<u>Synthesis and Evaluation of Information in Mathematics</u>** ★ 16.6-8.MAT.SE.001 Student interprets and applies methods of solving equations, inequalities, and/or situations involving variable quantities ★ 16.6-8.MAT.SE.002 Student demonstrates an understanding of the mathematical comparison ★ 16.6-8.MAT.SE.003 Student demonstrates an understanding of mathematical analysis **<u>Communication in Mathematics</u>** ★ 16.6-8.MAT.CO.001 Student is able to engage in mathematical communication	**<u>Algebra</u>** **Represent and analyze mathematical situations and structures using algebraic symbols** ★ develop an initial conceptual understanding of different uses of variables; ★ recognize and generate equivalent forms for simple algebraic expressions and solve linear equations **<u>Number & Operations</u>** **Understand numbers, ways of representing numbers, relationships among numbers, and number systems** ★ develop meaning for integers and represent and compare quantities with them **Understand meanings of operations and how they relate to one another** ★understand and use the inverse relationships of addition and subtraction, multiplication and division **<u>Process Standards</u>** **Problem Solving** ★build new mathematical knowledge through problem solving Solve problems that arise in mathematics and in other contexts **Connections** ★recognize and use connections among mathematical ideas ★recognize and apply mathematics in contexts outside of mathematics