6-2021

The Effectiveness of Socratic Teaching as an Intervention in the Instruction of High School Geometry for Students with Emotional Behavioral Disorders

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by

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A Thesis

Submitted to the Graduate Faculty of

St. Cloud State University

in Partial Fulfillment of the Requirements

for the Degree

Master of Science in

Special Education

June, 2021

Thesis Paper Committee:
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Abstract

High school students across the United States continue to struggle to attain mathematical proficiency, let alone achieve deep levels of conceptual knowledge in its various fields. This is particularly true for students with special needs. In this study, the effectiveness of the Socratic method was analyzed using a study on 13 students taking geometry with emotional-behavioral disorders (EBD), autism spectrum disorders (ASD), or other health disorders (OHD), including students with comorbidities between these. Six students were in the experimental group and received the Socratic method as an instructional method for a unit lasting approximately six weeks. Seven students were in the comparison group and received traditional instruction including direct and explicit instruction.

The Socratic method has been utilized in multiple fields outside of philosophy and mathematics with varying levels of success, including the subjects of law and political theory. After looking at the history of its use and effectiveness, this study attempts to establish initial evidence that the Socratic Method should be examined as a teaching intervention for students in high school geometry to develop in-depth knowledge of the subject. In small classroom settings, such as Federal Setting IV special education schools, dialectical conversations with students can flourish and the Socratic method can be implemented as a teaching tool. Its use was shown to be effective in developing depth of knowledge in geometry concepts and problem-solving processes for high school students with special needs. The Socratic method should be used in conjunction with traditional instructional approaches to deliver comprehensive geometry lessons and improve multiple aspects of student learning in the subject.

Keywords: Mathematics, Special Education, Socratic Method, Emotional-Behavioral Disorder

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Chapter 1: Introduction

The need for effective mathematics teaching interventions for students with emotional behavioral disorder (EBD) has become more apparent than ever before. Many of the nation's youth in the general education setting have been unable to meet mathematics proficiency standards (Cozad & Riccomini, 2016). To compound the deficit, recent evidence shows that, on average, students with EBD have not achieved at a level of same-aged peers in academia (Campbell et al., 2018). This is particularly true in the field of mathematics, where emotional intelligence has been shown to have a significant ability to predict mathematics achievement (Ugwuanyi et al., 2020).

The aim of this study was to examine the efficacy of a Socratic teaching intervention on students with EBD within the subject of geometry. A Socratic teaching intervention is one which utilizes the Socratic method to instruct. At the heart of the Socratic method is a conversational approach called dialectic. Dialectic is the process of eliciting the truth in conversation by means of guided questions aimed at opening out what is already implicitly known, or at exposing contradictions and muddles of an opponent's position (Blackburn, 2008). Specifically, the study is focused on answering the following research question: Given a Socratic teaching intervention in geometry, do high school students diagnosed with emotional-behavioral disorder demonstrate greater depth of knowledge in the subject than if they received no teaching intervention? Often the goal of geometry is not to simply memorize and apply a formula, such as the distance formula, but rather it is to understand how the formula was derived and why it holds true in every instance. Consequently, if it could be determined that this intervention was effective at teaching students how to arrive at answers in geometry while being able to sufficiently justify their answer, it would provide geometry teachers with an effective tool to use in teaching one of the most challenging subjects for many students with EBD.

It has been shown in previous studies that teachers who begin dialogues with students while utilizing questions of analysis can have a significant and positive impact on their learning (Hattie & Timperley, 2007). The Socratic method is one which uses such inquiry as a basis for instruction and has been modeled for millennia with high levels of success. In recent studies which utilized Socratic seminars as an instructional approach, students demonstrated improved critical thinking and language abilities (Billings & Fitzgerald, 2002; Pihlgren, 2008). Nonetheless, researchers have continued to stress the importance of further studies surrounding the efficacy of Socratic teaching methods (Nouri & Pihlgren, 2018).

The Socratic method that is utilized in this study was derived from examining Plato's dialogue, *Meno*. Now, the Socratic method is illustrated in almost all of Plato's works, but in *Meno* we are presented with Socrates working with a young boy, a slave without any prior education. Socrates begins by demonstrating how halving and doubling affects the length of a line. He then builds upon such premises by using his dialectical approach in conversation to guide the boy to a point where he understands how the hypotenuse of a right triangle is equal to the root of the sum of squaring the other two sides. That is, the boy learns the Pythagorean Theorem. What is unique about this instructional approach is that Socrates never told the boy any answers, but only asked him leading questions (Cooper, 1997). The demonstration Socrates gave was spurred by Meno's paradox, where, when pushed to provide a proper definition of virtue, he asks Socrates, "How will you look for it, Socrates, when you do not know at all what it is? How will you aim to search for something you do not know at all? If you should meet with it, how will you know that this is the thing that you did not know?" (Cooper, 1997, p. 880). The instructional demonstration was meant to illustrate the fact that the student does not directly discover anything new, nor does Socrates teach him anything. The word "teach," here, refers to the direct sense of adding new pieces of information to the boy's bank of knowledge; this can be likened to the modern understanding of explicit instruction. Rather than teach in the traditional method of explicit instruction, the instruction Socrates gave the boy allowed for the boy's natural capacity to reason to arrive at conclusions the boy did not previously realize. In the words of Socrates, the boy, instead of learning something new, recollected this knowledge. When explaining his instructional approach to Meno, Socrates told us his method directly by stating, "I shall do nothing more than ask questions and not teach him" (Cooper, 1997, p. 884). Then, after showing his teaching method to Meno through instruction of the boy, he asked, "What do you think, Meno? Has he, in his answers, expressed any opinion that was not his own?" (Cooper, 1997, p. 885). Using what Socrates directly states about his approach in *Meno*, as well as extracting his method from examining his instruction of the boy, a repeatable, testable method is used in this study.

This study focuses specifically on the subject of geometry, as opposed to other fields of mathematics, for multiple reasons. Geometry is a highly deductive field based on definitions, which suits the Socratic method - this will become more apparent when the method is discussed in later chapters. Also, when Socrates sought a satisfactory answer (as was the case when seeking a definition of virtue), definitions in geometry were often that which Socrates referred to as the standard by which proper definitions should be established (Cooper, 1997). Finally, Socrates himself showed us his instructional approach when teaching geometric concepts to the boy (Cooper, 1997). Based on these given reasons, it is likely that if this intervention is to be successful in a mathematics intervention, it will be so in the subfield of geometry.

Definition of Terms

Aporia is a serious perplexity or insoluble problem. The Socratic method of raising problems without providing solutions is sometimes referred to as the aporetic method (Blackburn, 2008).

Autism Spectrum Disorder (ASD). To meet diagnostic criteria for ASD one must display persistent deficits all three areas of social communication and interaction (deficits in social reciprocity, nonverbal communicative behaviors, and developing, maintaining, or understanding relationships) plus at least two of four types of restricted, repetitive behaviors (stereotyped/repetitive motor movements, insistence on routines/patterns, restricted/fixated interests, or hyper/hyporeactivity to sensory input) (Centers for Disease Control and Prevention, 2020).

Conceptual Knowledge. Conceptual knowledge is the understanding an individual has of how significant concepts relate to each other. It also involves the ability to apply that knowledge across different systems and novel situations (Robinson & Dube, 2009).

Deduction is the process of reasoning in which a conclusion is arrived at from a set of premises (Blackburn, 2008).

Describe and Demonstrate (Model) is the practice of instruction where the teacher works through problems with explanations and metacognitive think-alouds (Miller & Mercer, 1993).

Dialectic. From the Greek, *dialektike*, the art of conversation or debate. Fundamentally, the process of reasoning to obtain truth and knowledge. In the Socratic method, dialectic is the process of eliciting the truth by means of questions aimed at opening out what is already implicitly known, or at exposing the contradictions and muddles of an opponent's position (Blackburn, 2008).

Elenchus is cross-examination. In Plato, the dialectical or Socratic method of eliciting truth by cross-examination, often by refutation of contradictory propositions (Blackburn, 2008).

Emotional-Behavioral Disorder (EBD). An emotional and behavioral disorder is an emotional disability characterized by the following:

(i.) an inability to build or maintain satisfactory interpersonal relationships with peers and/or teachers;

(ii.) an inability to learn which is not derived from intellectual, sensory, or health factors;

(iii.) a consistent or chronic display of inappropriate behavior or feelings under usual conditions;

(iv.) a constant mood of unhappiness or depression;

(v.) a tendency to develop physical symptoms, pains or unreasonable fears associated with personal or school problems.

Children with EBD who exhibit one or more of the above qualities for sufficient duration, frequency and intensity that it interferes significantly with performance to the extent that special educational services are necessary. EBD is characterized by excess, deficiency, or disturbances of behavior. This difficulty is due to emotional irregularity and cannot be sufficiently explained by intellectual, cultural, sensory health factors, or other additional factors which might exclude EBD (Georgia Department of Education, 2020).

Epistemology is a theory of knowledge and its origins. In Greek, *episteme* means knowledge, and *logos* means the rational (logical) account of (Blackburn, 2008).

Explicit Instruction is direct instruction that additionally provides demonstration and modeling for solving problems, examples for accurately completing problems, practice opportunities, and stresses the importance of dialogue and feedback (National Mathematics Advisory Panel, 2008).

Federal Setting IV is a setting for students in special education who are taught at a separate school from the general education population (Minnesota Department of Education, 2021).

Guided Practice is a segment of instruction where students work through problems with the aid of a teacher who provides cues and feedback as needed (Miller & Mercer, 1993).

Individualized Education Program (IEP) is an education plan developed by a team of educators, psychologists, and specialists to meet the needs of students in special education (Minnesota Department of Education, 2021).

Induction is a term widely used for any process of reasoning that takes one from empirical premises to empirical conclusions supported by the premises, but not deductively entailed by them (Blackburn, 2008).

Learning Disability. Learning disabilities are disorders that affect the ability to understand or use spoken or written language, do mathematical calculations, coordinate movements, or direct attention (National Institute of Neurological Disorders and Stroke, 2020).

Metaphysics is any inquiry that raises questions about reality that lie beyond or behind those capable of being tackled by the methods of science (Blackburn, 2008).

Procedural Knowledge. Procedural knowledge requires understanding steps to carry out activities or to perform tasks (Miller & Hudson, 2007).

Recollection. From the Greek, *anamnesis*. Plato uses it to refer to the recollection of knowledge, obtained in a previous state of existence. The doctrine is an attempt to account for the innate unlearned character of knowledge of first principles (Blackburn, 2008).

Scaffolding is an incremental instructional approach meant to meet students where they are at in their current development while introducing material that is slightly more challenging to the point of independent mastery of the subject matter (Minnesota Department of Education, 2021).

Teaching Intervention is a strategic mode of delivering instruction designed to help improve student performance, typically in an area where the student is struggling (Minnesota Department of Education, 2021).

Chapter 2: Review of Related Literature

This section covers a range of literature that is intended to put the Socratic method in context with other mathematics interventions for students with special needs, the majority of which are intended to address the needs of students with EBD. There are multiple interventions which fit under the umbrella of the Socratic method in that they can be used jointly with the method during class instruction. This section also looks at a study which utilized a Socratic approach as its primary form of instructional delivery. Prior to this, however, this chapter begins by examining how the Socratic method has been used successfully in other fields of education.

Depth of knowledge surrounding a concept is ultimately the goal for students, as the purpose of developing conceptual knowledge is for them to have a deeper understanding than simply knowing the correct answer; they must be able to justify their answers. Included in this is conceptual knowledge which requires students to relate significant mathematical concepts while being able to apply their knowledge of these concepts to novel situations and different systems (Robinson & Dube, 2009).

Records of Success Using the Socratic Method

The Socratic method has a history of use in a wide variety of fields. Looking into successful cases can illustrate the breadth of its use and the plausibility of its success in the field of special education geometry instruction. Perhaps the most powerful of all of Plato's works is the *Apology* where Socrates was depicted defending himself against the charges of corrupting the youth as well as worshipping deities not sanctioned by Athens. It was in this setting that the power of the Socratic method was illustrated in a court of law (Cooper, 1997). In a study done by Alanzi (2020) the Socratic Method, along with the Case Method and Problem-Based Method, has been the most dominant and common legal training approach in the United States. The dialectical method has been used solely in legal education; however, its use has had even greater success when integrated with other forms of legal education. As students learning under the Socratic model are active learners, they are more likely to have greater success (Alanzi, 2020).

The Socratic method has also been used in law school as a test for students who were rigorously analyzed by their professors to provide students with the skills necessary to reflect upon their own law cases. There is not a universally accepted definition as to what constitutes the Socratic method in the legal community, making its practice slightly varied, but the common thread includes asking the interlocutor a series of questions without providing direct information resulting in a deeper understanding of the topic or, at the very least, an awakening which reveals one's ignorance or misconceptions. For this reason, according to an analysis by Taylor and Kroh (2009), the method has been taught to be pedagogical, causing limitations in its effect in the practice of law.

Aside from the impact the Socratic method has had in the field of law, it has also been utilized with great efficacy in various fields of education. The method has been used to teach critical thinking skills in college classrooms for those entering public relations. One study by Tallent and Barnes (2015) demonstrated how the Socratic method can be used effectively to encourage active learning. Many students who participated were, for the first time in their lives, being taught by not being given a "right" answer, but rather were given the opportunity to arrive at their own original conclusions.

Specific to the field of education, the Socratic method has been shown it can be effective in developing critical thinking, language, and relational skills when working with students diagnosed with ASD (Nouri & Pihlgren, 2018) as well as students with developmental disabilities (Colombos, 2020) and those who are learning English as a second language (Al-Darwish, 2012) if it is implemented properly in the classroom. There have also been cases of the Socratic method being implemented with success in physics classrooms where specialized questions are designed to recreate a Socratic dialogue as a part of physics instruction (Riveros, 2019). Due to the history of success using the Socratic method in various fields and classroom settings, it is reasonable to think that it can be successful in a number of other educational settings where it has yet to be attempted and thoroughly examined, such as a geometry classroom consisting of high school students with EBD.

Previously Attempted Mathematics Education Interventions and Approaches in Special Education

Aside from the typical difficulties students face in understanding mathematical concepts, students with EBD face additional challenges. Failure to remain engaged in lessons and initiate academic tasks during class can have long-lasting, negative consequences on the development of students' conceptual knowledge (Lee et al., 2012). In a study conducted by Lee et al., students with EBD were shown to have higher initiation rates on problems when given high-preference sequences. Further trials to initiate and maintain student engagement have been attempted by Haydon et al. (2012) by use of iPads in their classrooms. Using alternating instructional approaches, their study compared the use of worksheets against using an iPad for problem completion. In a high school math class for students with emotional disturbance, independent work was measured by visual analysis. The use of the iPad yielded higher levels of problem completion with greater success rates and overall higher engagement (Haydon et al., 2012).

Of course, simply attempting math problems does not alone improve student conceptual knowledge, that is only one step in the process towards deeper understanding. Many students, aside from those diagnosed with EBD, such as those with a learning disability (LD), struggle to attain proficiency levels on par with same-aged peers–let alone obtain a deep understanding of the topic on the level of conceptual knowledge. A cognitive instructional strategy known as "Solve It!" is an approach that has been attempted multiple times in the past with varying degrees of success. In particular, a study done by Montague et al. (2011) used this approach to study its effects on students with learning disabilities (LD). Comparing the results of eight research classes against 16 control classes (consisting of students ranging from low to high performing mathematical abilities) in middle school, this 7-month study yielded results which indicated that students who received the intervention demonstrated significantly greater growth in problem solving than the control groups. These results did not significantly differ between low-achieving and average-achieving students, nor between students with LD or those without (Montague et al., 2011).

Explicit inquiry routine (EIR) is another approach that seeks to bridge the gap between students' with LD actual achievement levels and proficiency levels in mathematics. This approach uses practices common to general education mathematics instruction, including dialogue and inquiry-based instruction, along with intensive, explicit instruction typically seen in special education settings (Scheuermann et al., 2009). At the onset, this approach was designed to engage students using concrete-representational-abstract (CRA) modes of instruction, using illustration and manipulatives to gain a deeper understanding of how to solve and apply one-variable equations. This practice showed promising results, with an average increase in scores for up to 11 weeks even after the program was completed (Scheuermann et al., 2009). Another study which looked at how CRA modes of instruction affect high school students' with LD mathematical abilities was conducted by Strickland and Maccini (2012) where they integrated the CRA strategy into lessons involving area which utilize multiplication of linear expressions. This research examined the results of three high school students with LD who used concrete manipulatives, drawings, and algebraic notation provided on a graphic organizer known as an expansion box to tackle area problems. The results showed that these students' conceptual understanding improved when multiplying linear expressions by being able to generalize the procedure to other contextualized area problems with success for up to 6 weeks after being given this instructional approach.

Although these studies were done on students with LD, the achievement gap which was demonstrated to be closed with these studies is something to be considered when working with students with EBD who exhibit similar deficits in mathematics. Further examination of studies conducted on students with EBD will help shed light on attempted interventions intended to yield similar results pertaining to mathematical achievement. One such study conducted by Mulcahy and Krezmien (2009) narrowed in on the effects of a contextualized instructional package on conceptual understanding of topics in geometry. This study, in particular, looked at area and perimeter problems presented to middle school students with EBD. Given real-life situations involving area and perimeter, students were provided with manipulatives and shown techniques to illustrate these concepts. The study asked students to participate in self-monitoring of behavior management, and the approach was shown to be effective in improving on-task behavior and accuracy.

Further research has shown that students with behavior disorders have had success with an intervention known as enhanced anchored instruction (EAI). This method is aimed at low-achieving students in mathematics. It uses a hands-on approach to solving math problems coupled with multimedia technology to aid students during instruction (Bottge et al., 2006). These rich problem-solving contexts are another example of an intervention that can benefit students with mild learning disabilities who struggle with problem-solving in mathematics, providing evidence which implies students have gained a more in-depth knowledge of mathematical concepts (Bottge et al., 2007).

A mathematical software known as Geogebra has been used in recent studies to assist students in understanding concepts which are traditionally difficult in calculus. This tool not only aids in student development but has an inhibiting factor in student attrition, which is common amongst students in new fields of mathematics they find difficult, such as calculus (Nobre et al., 2016). Continuing with the theme of electronic support tools was a study performed by Higgins et al. (2016). With the goal to improve mathematical reasoning abilities through a supplemental program called Math Learning Companion, students showed success with the program in not only reducing the rate of guessing but also increasing accuracy and mathematical reasoning.

As is evident from the studies discussed, a major trend in supplemental math instruction and directed teaching interventions involves the use of simple technology, such as manipulatives, and computer-assisted learning. Which leads one to wonder what place teachers have in the intervention process moving into the 21st century. What role do teachers, who have extensive knowledge of their subject matter, still play in closing the achievement gap for students who struggle with mastering concepts in mathematics to the point where they can justifiably be said to have conceptual understanding of the topic? Are there practices teachers can engage in with their students which cannot be replicated by use of manipulatives, representational models, self-monitoring, or computer programs?

To answer that, let us look at a practice dating back 2½ millennia, a method Socrates called dialectic, and practices that can be used in conjunction with it. Dialectic is the manner Socrates was known to converse in with his interlocutors where he would ask pointed, detailed questions. In every Platonic dialogue where Socrates was one of the main conversationalists, Socrates' objective was not simply to converse, but to gain knowledge, or at the very least to reveal misconceptions of his conversation partner and himself. The following section delves into interventions and instructional approaches that can be used in conjunction with dialectic and the Socratic method.

Instructional Practices that Accompany the Socratic Method

To say that Socrates only used the power of his words to educate would be false. He is shown to use a rudimentary graphic organizer when working with the boy in *Meno*. Socrates demonstrates this to us when he draws lines in the sand to show his student a square and the effect doubling the length of a side of a rectangle can have on the area (Cooper, p. 881-882). Within this framework, the technique of visual demonstration can be added under the umbrella of the Socratic teaching method. Ives (2007) illustrated how utilizing graphic organizers for secondary algebra students with LD can prove beneficial. In the study, a control group of students were given direct instruction along with strategies on how to solve linear equations while the research group was taught with these same methods in addition to a graphic organizer. The research group demonstrated higher accuracy in problem solving and results indicated greater conceptual knowledge through an understanding of related concepts.

To add credence to the power of visual demonstration in mathematics instruction, work done on eighth grade students with LD showed how diagrams aid in solving word problems. Given both one-step and multi-step word problems, students improved their ability to accurately solve such problems as well as create their own diagrams to represent novel, real-world problems and abstract mathematical relationships (van Garderen, 2007).

Demonstration in the age of Socrates relied on the use of sand and sticks to provide a visual representation. It is not realistic, nor advised in this study, to relegate teachers in the 21^{st} century to tools as rudimentary as these when using the Socratic teaching method as an intervention. Using a computer program, Geometer's Sketchpad, teachers have the option to utilize visual demonstration on angle measurements without the use of white boards or paper and pencil. This sketchpad allows for both static and dynamic visual representations of angles, wherein one can move rays about a focal point with another ray, creating different angle measures. Participants were asked to construct an angle of a specified measure and watch a ray sweep from its initial angle measure to the terminal ray of the angle that the student had just created before the computer displayed the angle measure created. Using this technology, 12 of 18 students ages 9 through 12 showed improvement (Cullen et al., 2018). Regardless of the age of students these studies were conducted on, manipulatives utilized with success in elementary-aged students have shown to elicit similar success in teaching concepts to students in high school (Freund & Rich, 2005).

Aspects of the concrete-representational-abstract and the strategic instruction model (CRA-SIM), referred to earlier, can also be used within the framework of the Socratic method. In the CRA-SIM model, students work with concrete objects under explicit instruction. Fading out the concrete instructional phase, students work through problems by creating visual representations (often by drawing) of the problem under guided practice. Once a student has mastered solving the problem using drawings, they are presented with an algorithmic process to solve the problem with a mnemonic device to help in remembering the process. A study done by Flores et al. (2019) focused on arithmetic instruction using CRA-SIM, with the aim to develop conceptual understanding. The CRA-SIM study showed improvement in student performance, with a significant difference in improvement of those who were administered CRA-SIM compared to students who were given direct instruction. The three phases can all be utilized alongside the Socratic method where explicit instruction and guided practice would be substituted using dialectic and guided questions. The use of demonstration is provided in both methods with the aim to develop conceptual understanding as the end result.

Previously Attempted Socratic Intervention

A supplemental math program which used the Socratic method in its seminars, where instruction was delivered through a series of questions posed to the class, aimed to develop critical thinking skills and articulation abilities of mathematical concepts in third- through eighth-graders. Unfortunately, the data presented did not meet evidence standards, thus no official results could be concluded from the study (What Works Clearinghouse, 2012). Consequently, additional research is needed to determine the effectiveness of such a teaching method.

As has been shown in the review of literature, the Socratic method has a history of success in various fields of education. The goal of this study is to add to the body of work on the efficacy of the Socratic method as a mathematics teaching intervention, specifically in the field of geometry when working with students with EBD as there is very little research done to this specificity. Many mathematical teaching interventions and methods that have been successful involve strategies that take the teacher out of the forefront. An intervention based around the Socratic method puts the instructor back in a vital role of education as the student's primary interlocutor. There are many other strategies under the umbrella of the Socratic method that can be incorporated into or used in conjunction with instruction to potentially aid or bolster the educational process. This will become clearer in the next chapter when the Socratic method itself is expounded.

Chapter 3: Method

Introduction

The purpose of this study was to determine the effectiveness of the Socratic method as mathematics teaching intervention, specifically in the field of geometry for high school students with EBD in a Federal Setting IV facility. After laying out the research question, this chapter focuses on the participants in the study, followed by the setting. The Socratic method will then be broken down into a repeatable, instructional approach prior to a discussion of the research method. The experimental method comes after a thorough discussion of the Socratic method. The questions used to determine meaningful answers will then be shown as a means by which to measure the effectiveness of the intervention. The final section of this chapter is used to discuss the limitations of the study.

Research Question

Given a Socratic teaching intervention in geometry, do high school students diagnosed with emotional-behavioral disorder demonstrate greater depth of knowledge in the subject than if they received no teaching intervention?

Participants

The study consisted of six research participants ages 16 to 18 years old, grades 10 through 12. Five of the students qualified for special education services under the category of EBD and one qualified for special education services under the category of ASD. All the students were male. Two students in the research group identified as black/African-American, one as white/Caucasian, and two as multi-racial. To maintain confidentiality, they are identified as “Student A” through “Student F" when results are discussed. Students B and E attended class online through Google Meet synchronously while Students A, C, D, and F attended in-person classes (at least part time). Students who participated virtually were able to hear the lesson and view the same demonstrations as those attending in-person classes. They were able to verbally communicate to the teacher and all classmates through a webcam and microphone.

The comparison group consisted of seven research participants ages 16 to 18 in grades 10 through 12. Six students in the comparison group qualified for special education services under the category of "EBD" and one qualified for special education services under the category of "Other Health Disability." Five of the students were male, two were female. Four of the students in the comparison group identified as black/African-American, one as white/Caucasian, one as Hispanic, and one as multi-racial. To maintain confidentiality, they are referred to as "Student G" through "Student M" when results are discussed.

Setting

The study occurred in the midst of the COVID-19 pandemic, March through April of 2021, and thus a hybrid learning model was in place. Two students in the study attended school in person each school day, two of the students attended class virtually from home each school day, and one student attended school in-person 2 days per week while attending class virtually 3 days per week. Classes were held synchronously, meaning students at home attended at the same time as students who attended in person class. Students who attended virtually logged in through Google Meet. The classroom was equipped with a webcam, microphone, and speakers, so students and staff could see and hear each other virtually during class.

The school these students attended was at a Federal Setting IV high school in an upper-Midwest suburb. The program within the school from which the students were enrolled is a program with eight high school classes consisting of approximately 45 students in total. Classes were self-contained in that students were taught their core subjects in the same classroom with their special education teacher. The classrooms also had two paraprofessionals to support student learning primarily by helping keep students on task during class and redirect undesirable student behaviors.

The Socratic Method

According to Diener (2007), the fundamental premise of Socratic teaching is: "Socrates' assessment that he does not teach the boy is correct in that he gently guides the boy in a way that allows the boy's learning process to be fundamentally autonomous" (p. 144). Examining Plato's *Meno* we find an explicit example of Socratic teaching where he demonstrates his method to his primary interlocutor in the dialogue, Meno, by demonstrating to him that the student can arrive at correct conclusions without being explicitly instructed. We can extract the Socratic method to be replicated by teachers from a careful analysis of this text. In doing so, this method can be tested and measured for not only the purposes of this study, but in future research as well. The method can be broken down into six steps, as follows:

1. The teacher asks the student(s) preliminary questions to establish their current level of knowledge on the subject. These foundations of knowledge are used as premises upon which to build, or deduce rather, the conclusions desired in the lesson. We find this in *Meno* when Socrates asks the boy if he knows what a square figure is (after Socrates draws it in the sand) and that all sides in a square are equal, to which the boy agrees (Cooper, 1997, p. 881).

2. The teacher introduces concepts, or definitions, that are necessary to complete the problem at hand, asking leading questions to build from the students' currently known geometric concepts, using concrete or visual demonstrations when it is needed and is possible**.** According to Socrates, it is necessary to know what something's definition is if one is to derive anything from it. This is often what is needed in geometry, where proof writing is part of the curriculum. As Socrates stated in the Meno, "If I do not know what something is, how could I know what qualities it possesses?" (Cooper, 1997, pp. 871-872). Emphasis of this was shown after Socrates asked Meno about the definition of "shape." Meno went on to give him examples, such as circles and squares. Socrates implored him to come to a universal definition which would apply to every shape and is unique to only shapes. He stated: "tell me what this is which applies as much to the round as to the straight and which you call shape?" (Cooper, 1997, p. 874). Socrates went on to inquire: "What then is this to which the name applies?... I am seeking that which is the same in all cases" (Cooper, 1997, p. 875).
3. Combine key terms with the student's prior knowledge to form further deductions. This is drawn out by the instructor asking questions on prerequisite information needed to solve the math problem. For instance, Socrates asks the boy whether he knows that squares can be of different sizes (Cooper, 1997, p. 882).
4. Once necessary terminology is established, initial questions are asked about the topic that often serve as additional premises. These are asked, at times, (almost) rhetorically when the concept is quite obvious. An example we find in the text is

when Socrates asks the boy what happens to the area of a square when one side is doubled (in which case it becomes a rectangle). The boy understands that the area is multiplied by two (Cooper, 1997, p. 882). Socrates still elicits a response from his student even when the answer is obvious. When this occurs at the onset of the conversation, the response expected is usually a yes or no. Thus, the teacher and student establish some premises, or in case of geometry, new theorems to build from or refer back to later in the conversation.

5. The teacher continues to use dialectic in a question-and-answer format to lead the students to logical conclusions. In this step, teachers allow students to follow their reasoning even if they provide incorrect answers initially. Then through demonstration and questioning, the instructor leads the student to see that their understanding of the problem, or the answer they gave, is mistaken, often by revealing that their premises lead to contradictory conclusions. Socrates is depicted doing this when the boy thinks that doubling both sides of a square will double its area (Cooper, 1997, p. 882). Revealing contradictions in one's thought is a well-known part of the Socratic method and has subsequently gained a name, the elenchus. In *Meno*, after drawing a square with lengths twice as long as the original, the boy sees for himself that the area is, in fact, four times as large, not twice as large (Cooper, 1997, p. 882). The realization of ignorance is necessary for a student to have if they already have a preconceived misconception of the subject.
6. The teacher engages the student in dialectical scrutiny to ensure comprehensive knowledge of the subject. In this step, the teacher examines the student and how they

came to their conclusions as well as if they have deduced conclusions about the topic which demonstrate and a deeper understanding, if not comprehensive knowledge of the topic.

To clarify the process more fully, there are some things that should be stated when teaching with the Socratic method. The instructor uses questions to guide the student by keeping them within the scope of the problem (for example, by reminding the student of the initial question they are seeking to answer). It is also worth repeating that the instructor leads the student(s) toward understanding without ever giving explicit answers. Additionally, visual or concrete demonstrations are used as tools in Socratic questioning. This is made clear when he drew lines (of various lengths), angles, and shapes in the sand for the boy he was instructing.

Although not part of the method, Diener (2007) presented five characteristics or qualities that a teacher modeling the Socratic teaching method should embody to remain in the spirit of the Socratic method. The first characteristic Diener identified was that the teacher has knowledge of a subject that the student does not. Although Socrates does not assert any answers, it is clear that he has knowledge of geometry as he uses all of the correct terminology, draws the figures in the sand, and guides the conversation with his questions. The second characteristic identified by Diener was that the teacher shows the learner that the student is lacking knowledge. Plato depicted Socrates as asking the boy a series of questions, showing the boy that what he initially thought was the case with lengths and shapes was incorrect, leading to a state of aporia for the learner which is to later be overcome. We see Socrates explain this to Meno, “At first he (the boy) did not know what the basic line of the 8-foot square was; even now he does not yet know, but then he thought he knew, and answered confidently as if he did know, and he did not think himself at a loss, but now he does think himself at a loss, and as he does not know, neither does he think he knows" (Cooper, 1997, p. 883). He went on to point out to Meno, "Look then how he will come out of his perplexity while searching along with me. I shall do nothing more than ask questions and not teach him." (Cooper, 1997, p. 884). A third quality noted by Diener is that a teacher helps the student reveal information to themself by asking questions which lead the learner to recognize the logical implications of their initial beliefs. Asking guided questions is the crucial component as these questions can be used to aid students in forming new, improved opinions on the topic. At no point during the instructional display did Socrates state solutions to the problem they were working on. The fourth characteristic Diener pointed out is that a sign the teacher has successfully educated the student is if the student is able to defend his opinions on the topic through dialectical scrutiny. The final characteristic identified in this Socratic display of education is that a teacher makes use of demonstrations, such as drawing lines of different length in the sand, while asking the student probing questions about the demonstration to ensure the student is drawing accurate conclusions (Diener, 2007).

Scaffolding happens inherently in the dialectical process. By asking questions which establish what the student already knows or remembers about a certain topic (as well as prerequisite knowledge), the instructor is meeting the student where they are at in their learning process then asking them point by point to develop concepts within the student's current zone of proximal development. What makes this scaffolding intervention unique compared to other methods that use a scaffolding approach is that it is delivered in a dialectical fashion as opposed to using explicit instruction.

Although the Socratic method of instruction is over 2½ millennia old, it is nonetheless a viable option for a mathematics teaching intervention. Socrates relies on the metaphysical belief that the soul is reincarnated eternally to support his notion that all learning is actually recollection–innate knowledge retrieved from a previous state of being. In this sense, he argued that no one actually learns new things in that they go from zero-state of knowledge to a positive-state of knowledge. Instead, the knowledge was always within the individual and just needed to be roused in conversation. Now, we do not necessarily have to hold Socrates' proposed metaphysical position, that is, to believe in the existence of reincarnation, in order to believe that knowledge is something inherent in the human mind. Knowledge, here, may be considered in the broader sense of having a natural capacity to reason, to make logical implications, and use rational thought in order to deduce (and induce) what is true, what is real, or what is the case. This type of knowledge is something inherent in humans. In that sense, the teaching method used by Socrates to rouse the students' knowledge of geometrical principles is still a viable option to be used as an intensive instructional intervention.

Research Method

The research design consists of a 6-week course covering the geometric topics of line segments, angles, and angle pairs. It is a qualitative study measuring the degree of conceptual understanding students obtain using the Socratic method as a teaching intervention. The lessons will be taught in the following order:

1. Line Segments and the Segment Addition Postulate
2. Midpoints and Segment Bisectors
3. The Midpoint Formula

4. Angle Measurement and Classification
5. Congruent Angles
6. Angle Bisectors
7. Angle Properties and Theorems
8. Complementary Angles
9. Supplementary Angles
10. Vertical Angles

Measure

Baseline data were gathered from a pretest consisting of 10 questions covering the geometric concepts discussed above. Varying degrees of the quality of answers will be examined using a scale of 0 to 2. A score of 0 indicated the question was answered incorrectly without a sufficient justification for how they arrived at the answer (by giving reasons for why the process followed to solve the problem is the correct process), a score of 1 indicated the question was answered correctly but without sufficient justification or that sufficient justification was provided but there was an error in computation in the arithmetic or algebra, and a score of 2 indicated the question was answered correctly and with sufficient justification. After completing the unit across an approximate 6-week time frame, students will be given the same 10 questions with different numerical values and the answers was used to measure improvement. The experimental group will be administered instruction using the Socratic method while the comparison group will be administered instruction using traditional methods including direct and explicit instruction.

Chapter 4: Results

The purpose of this study was to determine whether high school students with emotional-behavioral disorders demonstrate greater depth of knowledge in geometry topics after receiving a Socratic teaching intervention than students who did not receive the intervention. The study used two groups of students–the experimental group who received the intervention, and a comparison group who received traditional instruction–whose growth in depth of knowledge was measured using a pretest and a post-test. Questions on the pretest and post-test were scored using a 0 - 2 scale, where a score of 0 indicated the question was answered incorrectly, a score of 1 indicated the question was answered correctly but without sufficient justification or that sufficient justification was provided but there was an error in computation, and a score of 2 indicated the question was answered correctly and with sufficient justification.

Experimental Group

The experimental group consisted of six students (Students A through F) who received the Socratic method teaching intervention instead of receiving traditional instruction in high school geometry. Student A was a 16-year-old sophomore with EBD who scored a 4 out of 20 on his pre-assessment, getting correct answers on three questions while providing a sufficient justification for the answers on one of those questions. After the intervention, he scored a 15.5 out of 20 on the post-assessment, delivering correct answers on 6.5 of the questions (receiving half credit on question number 3 by correctly solving for the y-coordinate but not the x-coordinate) while providing sufficient justification for his answers on six questions. There were also three questions where he calculated the algebra or arithmetic incorrectly but was able to provide the geometric principles and algebraic or arithmetic process sufficiently to justify the problem-solving process.

Student B was a 17-year-old senior with EBD who scored 10 out of 20 on the pre-assessment, earning correct answers to six questions while being able to provide sufficient justification to four of those questions. After the intervention, he scored a 15 out of 20 on the post-assessment, delivering correct answers on eight of the questions and providing sufficient justification for six of the answers. He also provided sufficient justification on question number 6 but failed to compute the correct answer.

Student C was a 16-year-old junior with EBD who scored 5 out of 20 on the pre-assessment, scoring correct answers on three questions while providing sufficient justification on two questions. After the intervention, he scored 7 out of 20 on the post-assessment, answering five answers correctly while providing sufficient justification on two of those questions.

Student D was an 18-year-old senior with ASD who scored 11 out of 20 on the pre-assessment, correctly answering six questions while providing sufficient justification for four of those questions. He also gave sufficient justification for his answer on question number 7, but he failed to compute the answer correctly. His post-assessment score after the Socratic teaching intervention was 16 out of 20, correctly answering eight questions while providing sufficient justification on all eight of those questions.

Student E was an 18-year-old senior with EBD who scored 1 out of 20 on the pre-assessment, correctly answering one question with 0 sufficient justifications. After the intervention, he scored 3 out of 20 on the post-assessment, answering two questions correctly while justifying the answer to one of those questions sufficiently.

Student F was an 18-year-old senior with EBD who scored 4 out of 20 on the pre-assessment, correctly answering two questions with sufficient justification for both answers. After the intervention, the student scored 7 out of 20 on the post-assessment, delivering correct answers on three questions while providing sufficient reasoning for all three of those answers. He also provided adequate reasoning for how to solve question number 5, but he did not subtract correctly.

Figure 1 below shows the results of the experimental group's total scores on the pre-assessment and post-assessment.

Figure 1

Experimental Group Total Scores

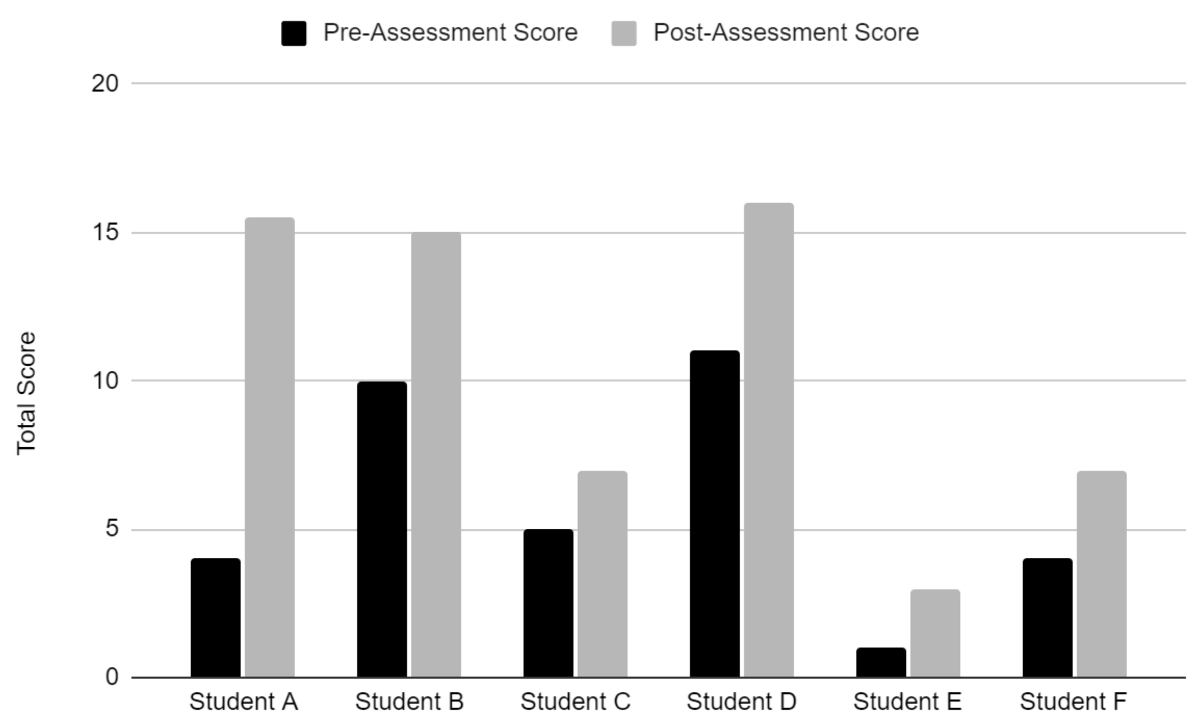


Figure 2 below shows the results of the answer scores strictly on the pre-assessments and post-assessments of the experimental group.

Figure 2

Experimental Group Answer Scores

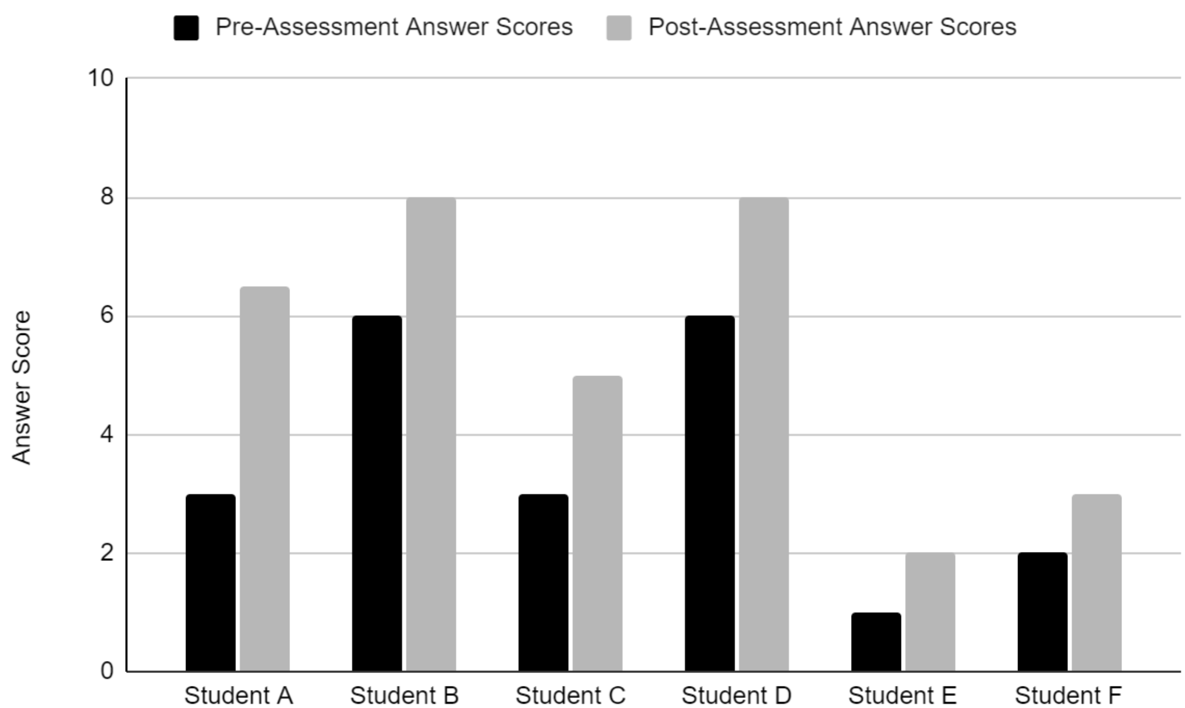
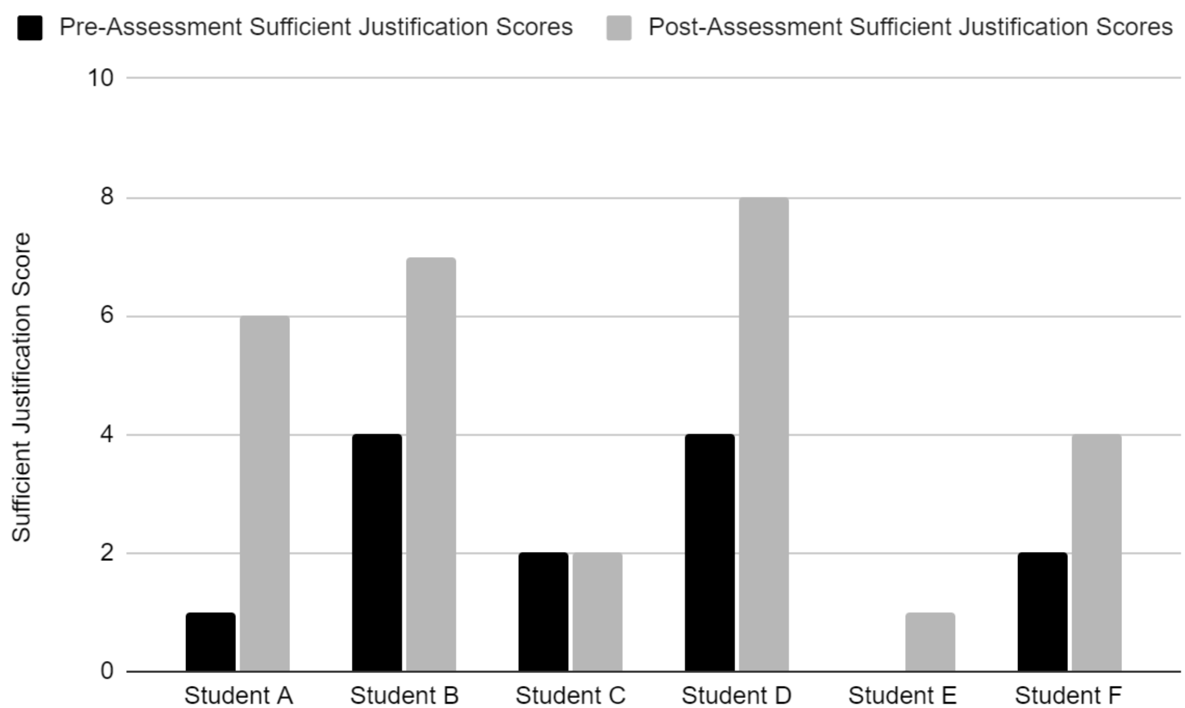


Figure 3 below shows the results of the sufficient justification scores of the pre-assessments and post-assessments taken by the experimental group.

Figure 3

Experimental Group Sufficient Justification Scores



Comparison Group

The comparison group consisted of seven students who received traditional instructional instruction consisting of direct and explicit approaches while covering the same geometry content as the experimental group. Student G was a 17-year-old junior with EBD who scored a 2.5 out of 20 on her pre-assessment, getting correct answers on 1.5 questions (receiving half credit on question number 8) while providing sufficient justification for the answers on one of those questions. After traditional instruction, she scored a 9.5 out of 20 on the post-assessment, delivering correct answers on 7.5 of the questions (receiving half credit on question 8) while providing sufficient justification for her answers on two questions.

Student H was a 17-year-old junior with OHD who scored 8 out of 20 on the pre-assessment, getting correct answers to five questions while being able to provide sufficient justification for three of those questions. After traditional instruction, he scored a 17.5 out of 20 on the post-assessment, delivering correct answers on 9.5 of the questions (receiving half credit on question number 3) and providing sufficient justification for eight of the answers.

Student I was a 16-year-old junior with EBD who scored 0 out of 20 on the pre-assessment, scoring correct answers on zero questions while providing sufficient justification on zero questions. After traditional instruction, he scored 12 out of 20 on the post-assessment, answering seven answers correctly while providing sufficient justification on five of those questions.

Student J was a 16-year-old sophomore with EBD who scored 0 out of 20 on the pre-assessment, correctly answering zero questions while providing sufficient justification for zero of those questions. Her post-assessment score after traditional instruction was 2 out of 20, correctly answering two questions while providing sufficient justification on zero of those questions.

Student K was a 17-year-old junior with EBD who scored 0 out of 20 on the pre-assessment, correctly answering one question with no justification. After traditional instruction, he scored 1 out of 20 on the post-assessment, answering one question correctly while justifying the answer to zero of the questions sufficiently.

Student L was a 17-year-old senior with EBD who scored 0 out of 20 on the pre-assessment, correctly answering zero questions with a sufficient justification score of 0. After traditional instruction was delivered, the student scored 0 out of 20 on the post-assessment, delivering correct answers on zero questions while failing to provide sufficient justification on any answers.

Student M was a 17-year-old junior with EBD who scored a 1 out of 20 on his pre-assessment, getting correct answers on one question while providing sufficient justification for the answers on zero of the questions. After traditional instruction, he scored a 2.5 out of 20 on the post-assessment, delivering correct answers on 1.5 of the questions (receiving half credit on number 8) while providing sufficient justification for his answers on one question.

Figure 4 below shows the results of the comparison group's total scores.

Figure 4

Comparison Group Total Scores

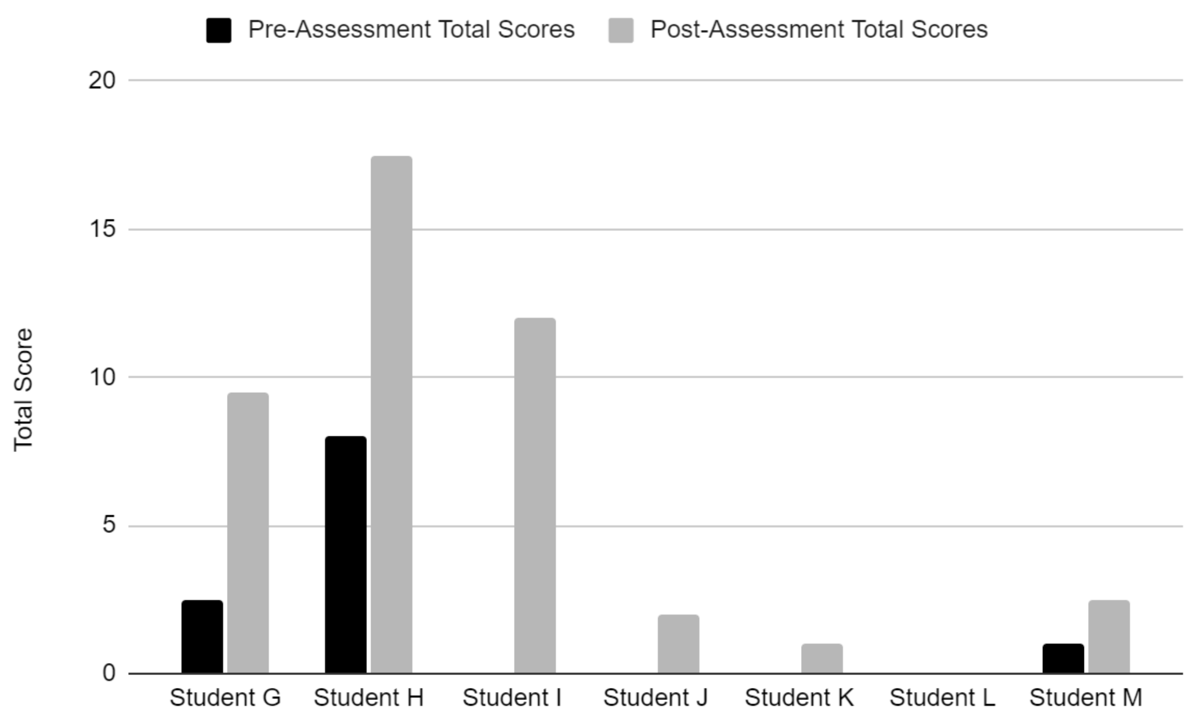


Figure 5 below shows the answer scores on the pre-assessments and post-assessments of the comparison group.

Figure 5

Comparison Group Answer Scores

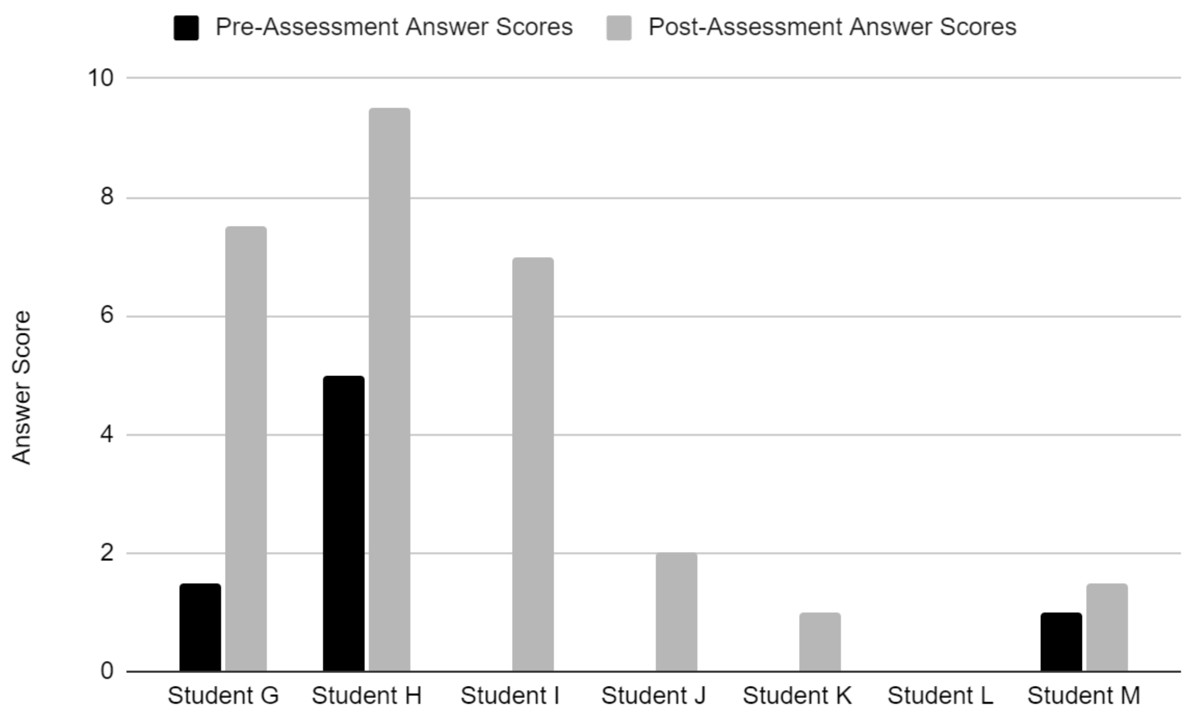
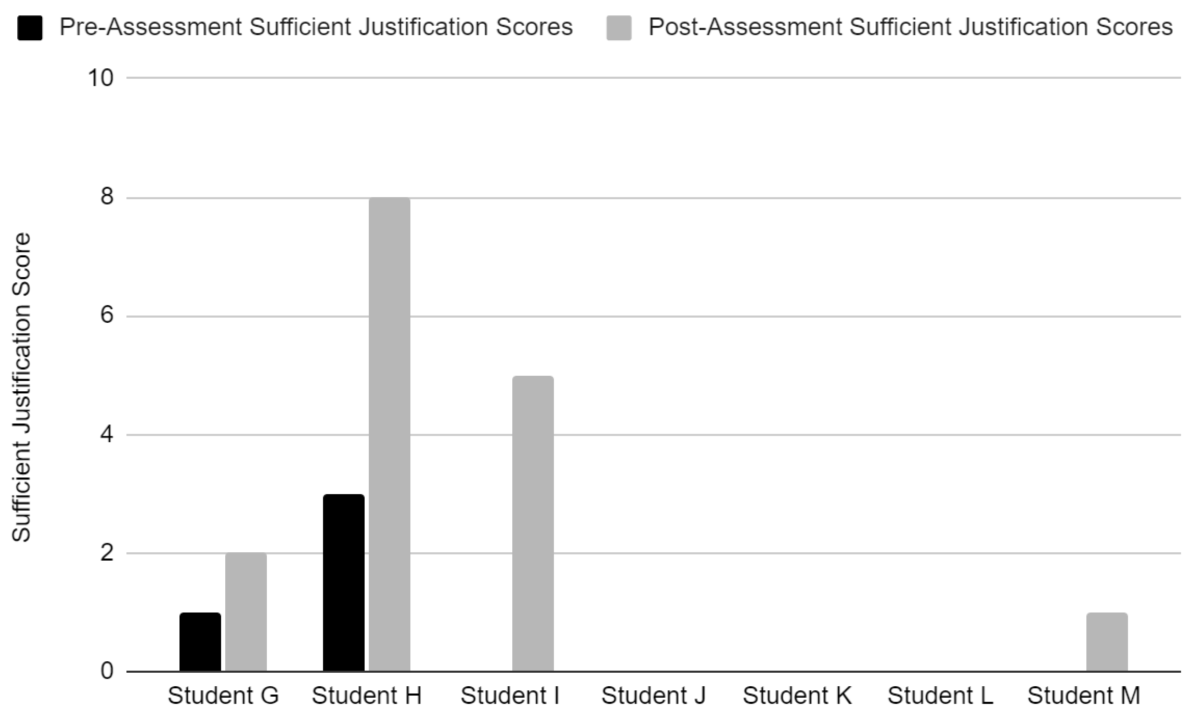


Figure 6 below shows the scores for sufficient justification in the pre-assessments and post-assessments for the comparison group.

Figure 6

Comparison Group Sufficient Justification Scores



Data Breakdown

In most cases of analysis, using the median would not provide statistical information that could be analyzed in a meaningful way, often providing a ratio not very telling of participant results (typically 4:3 or 3:4). Using the mean will allow for a more telling analysis of the differences and similarities in the data, which can then be used to draw more meaningful conclusions about the results of the study.

The mean growth between pre-assessment scores and post-assessment scores for the experimental group was an improvement in overall score of 4.75. The mean growth between pre-assessment scores and post-assessment scores for the comparison group was an improvement in overall score of 4.71. This difference is negligible.

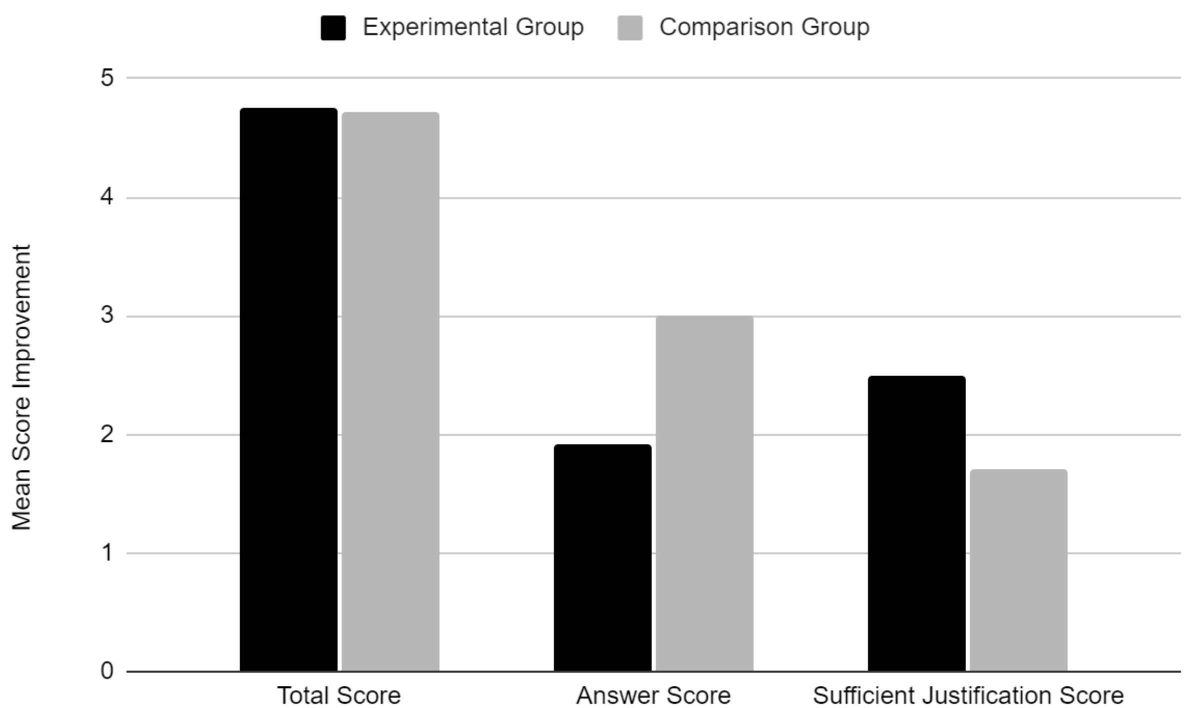
The mean growth strictly between correct answers on the pre-assessment and the post-assessment for the experimental group was an improvement of 1.92. The mean growth strictly between correct answers on the pre-assessment and the post-assessment for the comparison group was an improvement of 3. This difference suggests that traditional instruction is more effective at improving students' ability to arrive at the correct answer.

The mean score growth of sufficient justification between the pre-assessment and the post-assessment for the experimental group was an improvement of 2.5. The mean score growth of sufficient justification between the pre-assessment and the post-assessment for the experimental group was an improvement of 1.71. This difference suggests that the Socratic method is more effective at improving students' depth of understanding of geometry concepts and problem-solving processes.

Figure 7 below shows the mean improvement in total scores, answer scores, and sufficient justification scores between the experimental and comparison groups.

Figure 7

Score Improvements between Experimental and Comparison Groups



Data Analysis

When determining if the Socratic method is an effective teaching intervention in developing a deeper understanding of geometry concepts, improvement in the sufficient justification score is the piece of data that is the most important piece to examine as that score reflects the depth of knowledge the student gains on the given topic. It is certainly desirable for students to provide correct answers as well, but if the aim of the lesson is to improve the depth of knowledge in geometry concepts, then the ability to justify one's answer should be the focus.

This ability is reflected in the sufficient justification score, and the effectiveness of the Socratic teaching intervention to develop this ability is shown by examining the improvement of this score before and after the intervention has been delivered.

The mean improvement in scores of sufficient justifications for the experimental group was 30.21% higher than the mean improvement shown in the same group's correct answer score. The mean improvement of sufficient justification score was 75.44% lower than the improvement shown in correct answers for the comparison group. This indicates that the Socratic method is more effective than traditional methods at teaching for depth of knowledge in geometry. Furthermore, the mean improvement in the experimental group's mean answer score at 1.92 is greater than the mean improvement of the comparison group's mean sufficient justification score 1.71, indicating that the Socratic method is more effective at teaching students how to correctly solve problems in geometry than traditional instructional methods are at teaching students how to sufficiently justify their answers. Finally, the improvement in mean sufficient justification score for the experimental group was 46.2% higher than the improvement in the mean sufficient justification score for the comparison group. This is perhaps the strongest indication that the Socratic method is more effective at improving students' depth of knowledge in geometry than traditional methods. Based on the evidence, the Socratic method is an effective approach to teaching geometry concepts in an in-depth manner, such as when writing proofs or explaining the steps needed to solve a problem. There were some factors that should be taken into consideration when examining these results, however, as they may have impacted the results. These are the focus to the start of Chapter 5.

Chapter 5: Summary and Discussion

This section discusses the results of the study as they relate to the research question. This discussion begins with some varying factors that could have affected the results of the study, move into implications for how the Socratic method should be used, limitations of the study, and will end with recommendations for future research.

Varying Factors in the Study

Many factors contributed to the overall results of this study. Such factors include attendance of students, participation in class, initial levels of scoring, and the unique factor of students utilizing distance learning during a pandemic.

Beginning with the most unique variable that could potentially affect the results of this study, that of students participating in distance learning. There were only two students who did not attend in-person classes during the study, and both were in the experimental group. These students were Student B and Student E. They had improvements in their overall scores of 5 and 2, respectively, with improvements in answer scores of 2 and 1, respectively, and improvements in sufficient justification scores of 3 and 1, respectively. These gains were comparable to students who attended in-person classes.

A second factor to consider when analyzing the results of this study is the level of knowledge the students already had prior to the study. As the focus on the study was on development of conceptual knowledge, the improvement of scores was measured. A limitation in measuring improvement is that one can only improve as many points as they initially did not correctly score. The group that initially has a higher mean score on the pretest has less questions from which to gain points on when taking the post-test. The mean pretest score of the experimental group was 5.83 overall with a mean answer score of 3.5 and a mean sufficient justification score of 2.17. The mean pretest score of the comparison group was 1.64 overall with a mean answer score of 1.07 and a mean sufficient justification score of 0.57. The comparison group had more room for improvement.

The two other factors that must be considered as factors that could impact the results are attendance and participation. Attendance is a prerequisite for participation; thus, it is only when one is attending that they could be participating. Only when both conditions are met would they be considered engaged in the learning process. By multiplying the percentage of both attendance and participation, these factors can be grouped together as a means of establishing an engagement rate (the percent of time when students are both present and participating).

In the experimental group, Student A had an attendance rate of 60% and a participation rate of 68% which yielded 41% of the time when the student was engaged. Student B had an attendance rate of 30% and a participation rate of 90% which yielded 27% of the time when the student was engaged. Student C had an attendance rate of 27% and a participation rate of 75% which yielded 20% of the time when the student was engaged. Student D had an attendance rate of 90% and a participation rate of 80% which yielded 72% of the time when the student was engaged. Student E had an attendance rate of 60% and a participation rate of 38% which yielded 23% of the time when the student was engaged. Student F had an attendance rate of 27% and a participation rate of 80% which yielded 22% of the time when the student was engaged.

The mean engagement rate for the experimental group was 34%. The mean attendance rate for the experimental group was 49%. The mean participation rate for the experimental group was 72%.

In the comparison group, Student G had an attendance rate of 97% and a participation rate of 51% which yielded 49% of the time when the student was engaged. Student H had an attendance rate of 82% and a participation rate of 57% which yielded 47% of the time when the student was engaged. Student I had an attendance rate of 77% and a participation rate of 32% which yielded 25% of the time when the student was engaged. Student J had an attendance rate of 97% and a participation rate of 53% which yielded 51% of the time when the student was engaged. Student K had an attendance rate of 50% and a participation rate of 30% which yielded 15% of the time when the student was engaged. Student L had an attendance rate of 50% and a participation rate of 30% which yielded 15% of the time when the student was engaged. Student M had an attendance rate of 80% and a participation rate of 70% which yielded 56% of the time when the student was engaged.

The mean engagement rate for the comparison group was 37%. The mean attendance rate for the comparison group was 76%. The mean participation rate for the comparison group was 46%.

The difference between the mean engagement rates of the groups was a negligible 3% in favor of the comparison group. However, the difference between the mean attendance rates was 27% in favor of the comparison group while the difference between the mean participation rates was 26% in favor of the experimental group.

There are unique factors that follow solely from attendance rate. This includes the time between lessons for students. If a student missed multiple days throughout their education, there would have been less total instruction and longer lengths between the times they receive the lessons in the sequence, amongst many others. These may have had negative impacts on student score improvement.

The overall mean student attendance rate was 64% when accounting for both the experimental and comparison groups. The six students whose attendance rate was above the mean (Students D, G, H, I, J, and M), improved a mean of 6.2 points on their overall score, a mean of 3.67 points on their answer score, and a mean of 2.67 points on their sufficient justification score. The seven students whose attendance rate was below the mean (Students A, B, C, E, F, K, and L) improved a mean of 3.5 on their overall score, a mean of 1.5 on their answer score, and a mean of 1.6 on their sufficient justification score. The mean score of those students whose attendance rate was higher than the overall mean attendance rate was higher in all three scoring categories, indicating that attendance had an impact on student improvement in both answering questions correctly and in depth of knowledge on the topic.

There are also unique factors that stem solely from participation rate. These include the number of assignments completed and total number of repetitions of guided practice with the instructor, amongst many others. These may have had negative impacts on student score improvement. It could be further speculated that the difference in participation rates was due to a difference in instructional approaches wherein a question-driven instructional approach, such as the Socratric method, often leads to higher levels of participation. Further research would be needed to give weight to such a hypothesis.

The overall mean student participation rate was 58%. The six students whose participation rate was above the mean (Students A, B, C, D, F, and M) improved a mean of 4.67 points on their overall score, a mean of 1.83 points on their answer score, and a mean of 2.5

points on their sufficient justification score. The seven students whose participation rate was below the mean (Students E, G, H, I, J, K, and L) improved a mean of 4.79 on their overall score, a mean of 3.07 on their answer score, and a mean of 1.71 on their sufficient justification score. The mean score of those students whose participation rate was higher than the overall mean participation rate was higher in only the sufficient justification scoring category, indicating that participation had an impact on student improvement in depth of knowledge on the topic.

The overall mean engagement rate was 36%. The six students whose engagement rate was above the mean (Students A, D, G, H, J, and M) improved a mean of 6.08 points on their overall score, a mean of 3.08 points on their answer score, and a mean of 2.67 points on their sufficient justification score. The seven students whose engagement rate was below the mean (Students B, C, E, F, I, K, and L) improved a mean of 3.57 points on their overall score, a mean of 2 points on their answer score, and a mean of 1.57 points on their sufficient justification score. The mean score of those students whose engagement rate was higher than the overall mean engagement rate was higher in all three scoring categories, indicating that engagement had an impact on student improvement in both answering questions correctly and in depth of knowledge on the topic.

Implications for Practice

The implications of this study on teaching practices in the classroom should be considered with an eye towards the types of geometry problems that the Socratic method has shown to be effective on. Students in the experimental group indicated a higher rate of improvement on providing reasons for how they arrived at the answers they did while students in the comparison group indicated a higher rate of improvement on strictly arriving at the correct answer.

The implication is that the Socratic method should be used as a geometry teaching intervention for high school students with EBD when those students are having difficulties explaining their answers, justifying solutions, or writing proofs. For students who are new to the subject, the method may be a bit intense or overwhelming to the point where arriving at the solution may be overlooked in search of a more elaborate explanation. For those with a higher beginning level of knowledge, the method may be more effective in gaining a deeper understanding to provide more meaningful answers. The overall mean pretest score was 3.58. Of the six students (Students A, B, C, D, F, and H) whose pretest scores were higher than this, the mean answer score improvement was 2.5 points and the mean sufficient justification score improvement was 3.17 points. Of the seven students (Students E, G, I, J, K, L, and M) whose pretest scores were lower than the overall mean, the mean answer score improvement was 2.5 points–no difference from the group with higher beginning scores–and the mean sufficient justification score improvement was 1 point–2.17 points less than, or 32% of, the group with higher beginning scores–which indicates it may be the case that this method may be suitable for more advanced students.

The Socratic method can and should be used alongside other methods of instruction. A teaching regimen which would only utilize the Socratic method would not address the needs of all students in the classroom at all times (nor does solely using any one teaching method to teach every topic to every student). It has been shown to be effective in developing meaningful answers wherein the student is asked to justify their solutions (as in a proof) but would be bolstered by integrating its use with traditional instructional approaches to deliver a more comprehensive lesson.

Limitations of the Study

The limitations of this study include it consisting of a small sample size of six participants in the experimental group and seven in the comparison group. The effectiveness of the Socratic method on a larger number of participants would produce more thorough and clearer results.

This study was conducted in a Federal Setting IV special education facility with small classes consisting of five to sic students per classroom. The effectiveness of the Socratic method in larger classroom settings has not been determined based on this study.

The population of students was limited to those in high school with special needs, specifically students with EBD. The effectiveness of the Socratic method when working with a different population of students, such as those in different special needs programs, those in a general education setting, or those in a different grade range, has not been determined based on this study.

This study covered one geometry unit consisting of line segments, midpoints, angle pairs, angle relationships, and proofs involving these topics. The effectiveness of the Socratic method when working with different topics in geometry, fields of mathematics, or academic subjects aside from mathematics has not been determined based on this study.

Recommendations for Future Research

The effectiveness of the Socratic method as a teaching intervention for students with special needs is a topic with little research. Many special education settings have smaller classroom sizes allowing for more flexibility in teaching methods and individualized instruction. As the Socratic method is an intensive method of instruction which is most easily done with fewer students, it is a method of instruction realistically delivered in special education rendering it viable for further study.

Recommendations for further research include additional studies conducted in special education high school settings when teaching geometry to build a body of data that can be analyzed at a macro level. Additionally, the Socratic method is recommended for study in other fields of mathematics at the high school level including algebra, statistics, discrete mathematics, and calculus, in both general education and special education. Other content areas should also be explored utilizing the Socratic method as a teaching intervention to determine its scope in developing depth of knowledge throughout academia. Finally, the efficacy of the Socratic method should be researched for students in special education aside from those with EBD.

Conclusion

The Socratic method has shown to be able to develop student knowledge in the concepts of geometry beyond being able to correctly arrive at a solution. In small classroom settings, such as Federal Setting IV special education schools, dialectical conversations with students can flourish and the Socratic method can be implemented as a teaching tool. Its use was shown to be effective in developing depth of knowledge in geometry concepts and problem-solving processes for high school students with EBD. The Socratic method should be used in conjunction with traditional instructional approaches to deliver comprehensive geometry lessons and improve multiple aspects of student learning in the subject.

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Appendix A: Parent/Guardian Consent Form

Geometry Study

My name is Adam Wohl, and I am a special education teacher in your student's high school. I am also a graduate student at St. Cloud State University (SCSU). This form is being sent to ask your permission to allow your child to participate in a study being conducted for my Master's Degree at SCSU. Two consent forms—one for you, the parents/guardians, and the other for your child—are included. Both of these forms must be signed and returned prior to the start of the study, which I am hoping to begin the week of March 22nd.

Background Information and Purpose

The purpose of this study is to determine the efficacy of a mathematical teaching intervention modeled after the Socratic method in students' conceptual understanding of geometry. Collecting and analyzing data based on this method will help other teachers to utilize the most effective instructional methods for their students in the future.

Procedures

The study will be conducted over a 6-week period. During the study your student will be asked to take a pre-assessment to establish baseline results over 10 concepts in geometry. After 6 weeks of participating in math class at the same days, times, and location(s) they already have math instruction, they will take the same 10-question assessment and their improvement will be measured. After each lesson, students will be asked one or more of the questions as well to measure growth throughout the study. The intervention consists of students being given leading questions coupled with demonstration during instruction to arrive at conclusions on their own, as opposed to traditional explicit instruction where students are told how to solve a geometry problem.

Risks

Study participants may experience the following risks or discomforts, which are minimal: anxiety from taking an assessment, inhibition of a self-growth perspective. To help with any anxiety your child may experience, they will be given the option of taking an assessment in a private room, to speak with me about the study, provided all accommodations currently in their IEP, and they will be reminded that any assignment or assessment taken will not impact their grade any more than it would if they were not in the study.

Benefits

Study participants may also experience the following benefits: improved performance in geometry, improved view in one's academic ability, increased independence in mathematics.

Confidentiality

The name of your child will not be used when the results of the study are posted. All that will be used in the study's report are scores for measuring growth. The only individuals who will have access to participants' names will be the student's teacher and myself. The data will be stored either on digital file or on paper copy. Results will be used for a master's thesis paper with the possibility of publication in an education journal.

Contact Information/Research Results

If you are interested in the results of the research or have any additional questions please contact me at alwohl@district287.org or my advisor from SCSU, Dr. Bradley Kaffar at bjkaffar@stcloudstate.edu

Voluntary Participation/Withdrawal

If during the study you or your child decide that you do not want to continue to be a part of the study, simply inform me or your child's teacher and your child's results will be removed from the study. The decision to stop being in the study will not be held against you or your child and will not interfere with the current mathematical educational content credit earnings, or graduation path. Refusal/withdrawal will not impact your current or future relationship with me, your child's teacher, Ann Bremer Education Center, Intermediate School District 287, or SCSU.

Acceptance to Participate

Your signature indicates that you and your child have read the information provided here and have decided to participate. You or your child may withdraw from the study at any time without penalty after signing this form.

I look forward to having your children participate in this innovative study and I thank you in advance for your cooperation.

Student's Name:______________________________
Name:_______________________________________
Signature:___________________________________ Date:_______________

Adam Wohl, Special Education Instructor, Master's Student, Lead Researcher
alwohl@district287.org

Dr. Bradley Kaffar, Special Education Department Chair, SCSU
bjkaffar@stcloudstate.edu

Appendix B: Student Assent Form

Geometry Study

You are invited to participate in a research study involving a math instructional technique designed to improve your understanding of geometry. The study will take 6 weeks and is conducted during your typical math class.

Background and Purpose of Study

Mr. Adam is completing his teaching license, and as part of his graduation process he is seeing if a math teaching strategy is more effective than traditional methods. The purpose of this study is to see if teaching geometry using the Socratic method will help students learn geometry with greater understanding.

Procedures

The study will be done over a 6-week period. For the study you will be asked to take a pre-assessment of 10 questions on lines and angles. After 6 weeks of participating in math class you will take the same 10-question assessment to see if there was any change in results. After each lesson, students will be asked one or more of the questions. The intervention consists of some students being given only leading questions and demonstration during class to help them arrive at conclusions on their own, as opposed to traditional explicit instruction where students are told how to solve a geometry problem.

Risks

You may experience some anxiety from taking an assessment. To help with any anxiety you may experience, you will be given the option of taking an assessment in a private room, speak with Mr. Adam about the study, and you will be reminded that any assessment taken will not impact your grade any more than it would if you were not in the study.

Benefits

You may also experience the following benefits: improved understanding of geometry, a better view of your academic abilities, and increased independence in mathematics.

Confidentiality

Throughout the course of this study and in the final paper your name will be kept private and will not be shared.

Contact Information/Research Results

If you are interested in the results of the research or have any additional questions please contact Mr. Adam at alwohl@district287.org or my advisor, Dr. Bradley Kaffar at bjkaffar@stcloudstate.edu

Voluntary Participation/Withdrawal
If during the study you decide that you do not want to continue to be a part of the study, you need to tell Mr. Adam, your teacher, or your parents. Mr. Adam will make sure that your results are removed from the study. Your decision to stop being in the study will not be held against you and will not interfere with your current mathematical educational content or credit path. Refusal/withdrawal will not impact your current or future relationship with Mr. Adam, SCSU, ABEC, your teacher, or ISD 287.

Acceptance to Participate
When you sign your name on the line it means you understand this information and have agreed to be a part of the study.

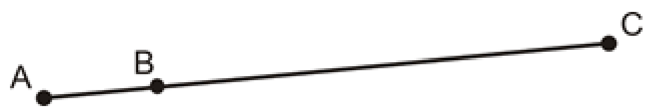
Name:___________________________________
Signature:________________________________ Date:______________

Appendix C: Pre-Assessment

Name:________________________

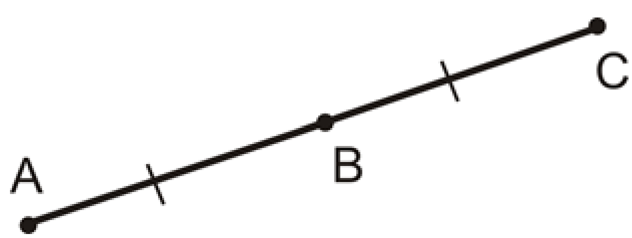
Geometry: Lines and Angles Pre-Assessment

1. Looking at the image below, line segment AC = 19 cm and line segment BC = 14 cm.



What is the length of line segment AB? How do you know?

2. In the line segment AC below, B is the midpoint.

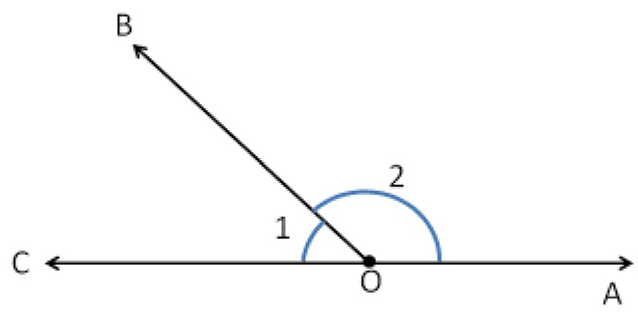


If line segment AB = 12 cm, what is the length of line segment AC? Why must this be the case?

3. Michael lives 5 blocks west and 8 blocks north of the center of town. Jamiah lives 11 blocks east and 4 blocks north of the center of town. If they wanted to meet at the midpoint between their homes, where would that point be from the center of town (how many blocks east or west and how many blocks north or south)? How did you arrive at that conclusion?

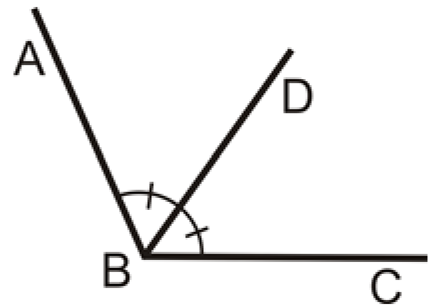
4. If you start with an obtuse angle then subtract this angle by 90°, what type of angle will you have? Why must this be the case?

5. In the image below, ∠1 = 35°.



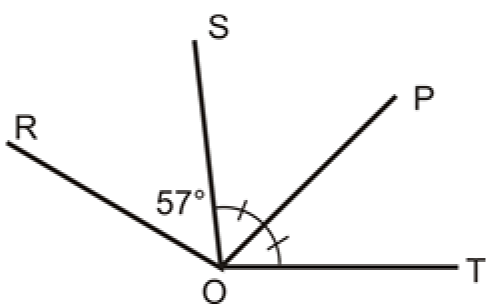
What is the measure of ∠2? How do you know?

6. In the image below, ∠ABD is congruent with ∠CBD.



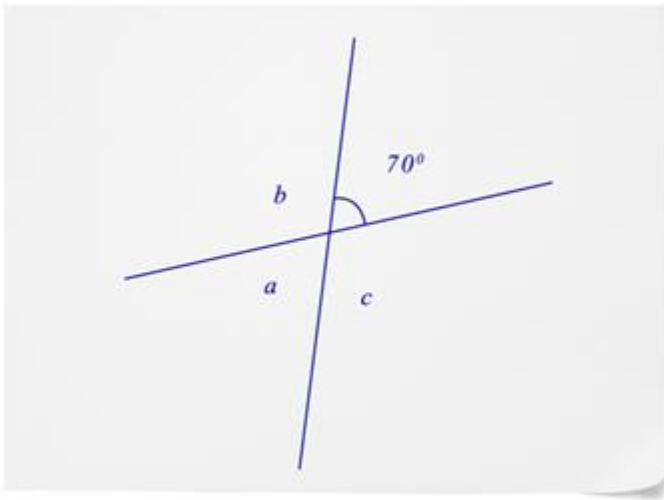
If ∠ABD = 75° - X and ∠CBD = 25° + X, what is the value of X? How do you know?

7. Line segment OP is the angle bisector of ∠SOT.



If ∠ROT = 153°, then ∠SOP = ? Why must this be the case?

8. Use the image below to find the values of ∠a, ∠b, and ∠c.



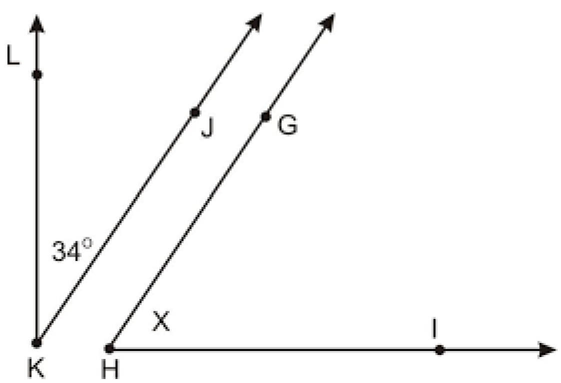
∠a =

∠b =

∠c =

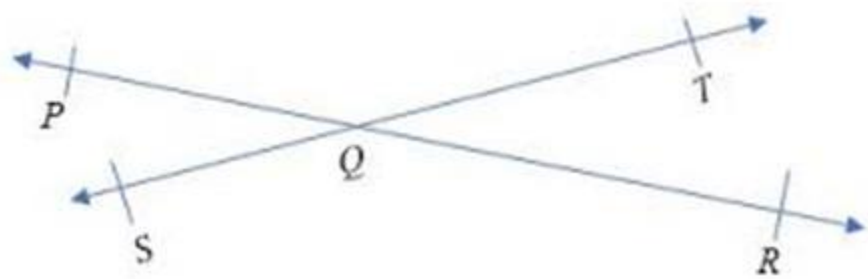
Why can these angles have no other measures than the ones found here?

9. Below, ∠LKJ and ∠GHI are complementary.



What is the value of the variable X? How do you know?

10. In the image below, ∠PQS = 15 + x and ∠TQR = 2x.



What is the value of ∠PQS? How do you know?

Appendix D: Post-Assessment

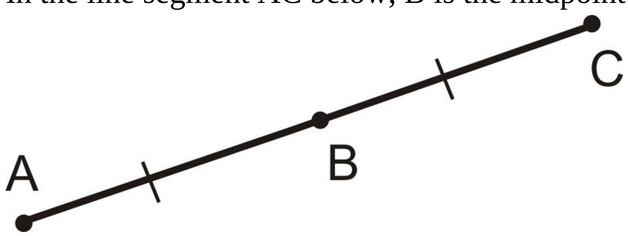
Name:________________________

Geometry: Lines and Angles Post-Assessment

1. Looking at the image below, line segment AC = 14 cm and line segment BC = 9 cm.

What is the length of line segment AB? How do you know?

2. In the line segment AC below, B is the midpoint.

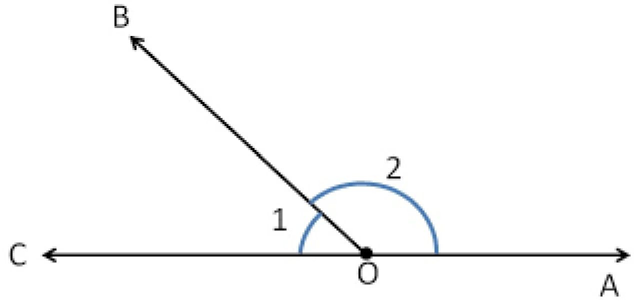


If line segment AB = 15 cm, what is the length of line segment AC? Why must this be the case?

3. Michael lives 3 blocks west and 10 blocks north of the center of town. Jamiah lives 9 blocks east and 6 blocks north of the center of town. If they wanted to meet at the midpoint between their homes, where would that point be from the center of town (how many blocks east or west and how many blocks north or south)? How did you arrive at that conclusion?

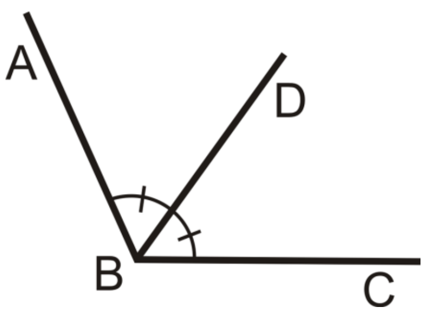
4. If you start with an acute angle then add this angle by 90°, what type of angle will you have? Why must this be the case?

5. In the image below, ∠1 = 25°.



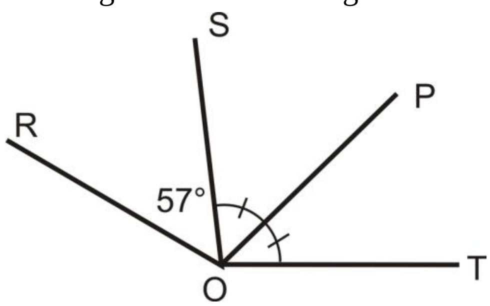
What is the measure of ∠2? How do you know?

6. In the image below, ∠ABD is congruent with ∠CBD.



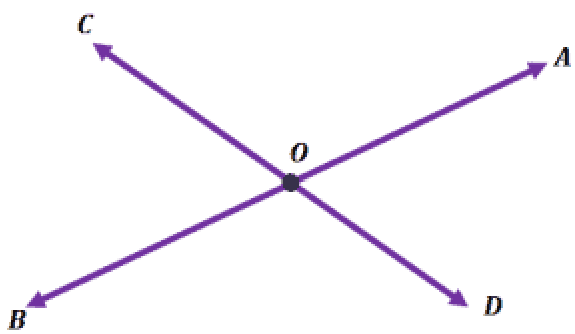
If ∠ABD = 110° - x and ∠CBD = x - 10°, what is the value of x? How do you know?

7. Line segment OP is the angle bisector of ∠SOT.



If ∠ROT = 167°, then ∠SOP = ? Why must this be the case?

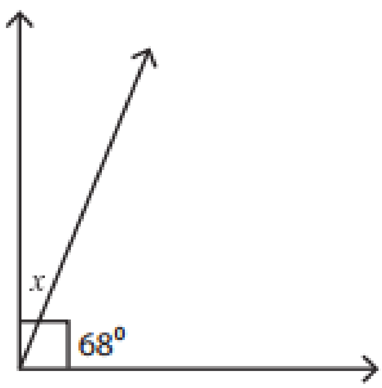
8. Use the image below to find the values of ∠COA, ∠COB, and ∠BOD if ∠DOA = 70°.



∠COA =
∠COB =
∠BOD =

Why can these angles have no other measures than the ones found here?

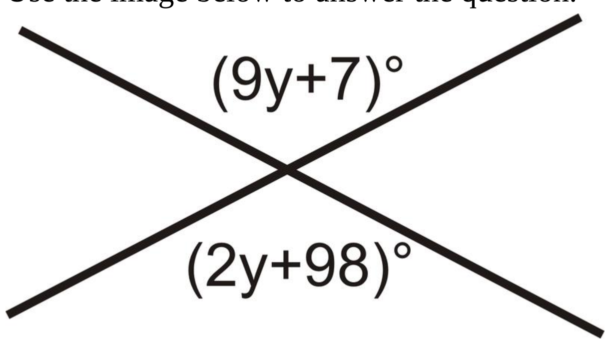
9. Below, the two angles are complementary.



$x =$ ________

What is the value of x? How do you know?

10. Use the image below to answer the question.



What is the value of y? How do you know?

Appendix E: IRB Decision Letter

ST. CLOUD STATE UNIVERSITY
EDUCATION FOR LIFE

Institutional Review Board (IRB)

720 4th Avenue South AS 210, St. Cloud, MN 56301-4498

Name: Adam Wohl

Email: alwohl@stcloudstate.edu

IRB PROTOCOL DETERMINATION:
Expedited Review-1

Project Title The Effectiveness of Socratic Teaching as an Intervention in the Instruction of high school Geometry for Students with Emotional-Behavioral Disorders

Advisor Bradley Kaffar

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects. Your project has been: **APPROVED**

Please note the following important information concerning IRB projects:
- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).

- For expedited or full board review, the principal investigator must submit a Continuing Review/Final Report form in advance of the expiration date indicated on this letter to report conclusion of the research or request an extension.

-Exempt review only requires the submission of a Continuing Review/Final Report form in advance of the expiration date indicated in this letter if an extension of time is needed.

- Approved consent forms display the official IRB stamp which documents approval and expiration dates. If a renewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc.). The IRB reserves the right to review the research at any time.

If we can be of further assistance, feel free to contact the IRB at 320-308-4932 or email ResearchNow@stcloudstate.edu and please reference the SCSU IRB number when corresponding.

IRB Chair:

Dr. Mili Mathew
Chair and Graduate Director
Assistant Professor
Communication Sciences and Disorders

IRB Institutional Official:

Maria-Claudia Tomany

Dr. Claudia Tomany
Associate Provost for Research
Dean of Graduate Studies

OFFICE USE ONLY

SCSU IRB#: 2016 - 2623	**Type:** Expedited Review-1	**Today's Date:** 3/9/2021
1st Year Approval Date: 3/8/2021	**2nd Year Approval Date:**	**3rd Year Approval Date:**
1st Year Expiration Date: 3/7/2022	**2nd Year Expiration Date:**	**3rd Year Expiration Date:**