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The effectiveness of the question formulation technique on open-ended, written response questions in mathematics

Jessica M. Mannion
Rowan University, jessica.mannion93@gmail.com

EFFECTIVENESS OF THE QUESTION FORMULATION TECHNIQUE ON OPEN-ENDED, WRITTEN RESPONSE QUESTIONS IN MATHEMATICS

by

Jessica M. Mannion

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Abstract

Jessica Mannion
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The purpose of this study was to determine the effectiveness of the Question Formulation Technique (QFT) on students' open-ended, written response questions in mathematics in a 4th grade inclusion classroom. Four students, three male and one female, participated in the study. All students were classified with specific learning disabilities (SLD) or other health impaired (OHI). Experimental research design was used. A baseline was collected using students previous written response scores. The QFT was implemented over the course of three math chapters. Students were assessed after each chapter with three open-ended, written response problems. The results show that each students average score increased after implementation of the Question Formulation Technique. Further research is needed to determine the extent to which the Question Formulation Technique is responsible for a change in student achievement.

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Chapter 1

Introduction

The art of teaching is constantly evolving as new methodologies are created and shared. Just as educators work to witness their students' skills grow over time, it is also educators themselves who have an opportunity to advance in their pedagogical skills throughout their career to become more effective teachers. Techniques used in the classroom should increase student understanding and lead to a higher level of achievement. In the 21st century world, students need the skills to question. Higher level questions have been shown to lead to higher student engagement and cognitive levels in the classroom (Marshall, 2012).

As of 2015, the United States ranks 38th in mathematics according to the Programme for International Student Assessment (PISA) administered by the Organization for Economic Co-operation and Development (OECD). The United States average score saw an 11 point drop from the previous assessment year, 2012. Teachers need to ensure they are using teaching strategies in math that will lead to higher student achievement

Math curriculums today now often include written response problems. In written responses, students are asked to state and support their answers with explanations of their process and procedure for solving the problem. Justifying their thinking has been shown to strengthen student understanding of concepts (Frank et al., 2009). The use of written response in mathematics has become commonplace in math classrooms and on math standardized assessments. The ability to explain one's thinking in a clear and concise manner can often be challenging for students. Students who are identified as eligible for

special education have added challenges when working to develop their written response skills as they may have various levels of cognitive or intellectual ability, attention or impulse difficulties, or other disabilities.

Metacognition is defined as one's ability to think about their thinking. Student's ability to think about their understanding of mathematical concepts and to reflect on their process when solving a problem can lead to a deeper understanding of the concept (Houston, 2017). Students are tasked with doing both of these when writing a written response in mathematics. One way to increase a student's metacognitive ability is to promote inquiry in the classroom (Houston, 2017). When students question, they are reflecting on their current knowledge and considering what they do not know about a particular topic. Through reflection of their current level of understanding, students practice the metacognitive process.

Techniques for teachers to implement in the classroom are constantly being created and shared. In today's technological world, new ideas can be shared faster than ever before as teachers and administrators can turn to the internet for the latest pedagogical strategies. While the quick spread of information is often beneficial, it is critical that techniques used in the classroom be studied to ensure their effectiveness in student achievement. A current technique gaining in popularity that reinforces metacognition is The Question Formulation Technique (QFT). The QFT is a process that teaches students to generate their own questions, improve their questions, determine how to use their questions to guide their learning, and to reflect on what and how they learned Questioning in teaching has a long history of being emphasized through the teacher, with the teacher asking the students question to engage them in curricular material. The QFT

flips that model by teaching the students to ask open-ended questions to engage students at the start of a unit and provide a sense of purpose throughout instruction.

Purpose of the Study

The purpose of this study is to investigate the effectiveness of the Question Formulation Technique for improving achievement on open-ended, written response math problems of 4th grade students who are identified as eligible for special education.

Research Question

- Does the Question Formulation Technique impact students' ability to complete open-ended, written response math problems?

Significance of the Study

The significance of this study is to determine if the Question Formulation Technique has a positive impact on student achievement in open-ended, written response questions in mathematics. Research studies have shown the positive impact the QFT can have on students curiosity (Clark, 2016), but limited research has been done to evaluate the impact of the technique on student achievement. With this research in mind, this study will seek to consider if the QFT will specifically improve student performance on open, ended written response questions in mathematics.

Key Terms

For the purpose of this study, the following terms are defined as follows:

1. **Question Formulation Technique (QFT)**: a stepwise process to teach students to ask more rigorous questions (Minigan, Westbrook, Rothstein, & Santana 2017)
2. **Metacognition**: awareness and understanding of one's own thought process

3. **Open-ended**: allowing the formulation of answers as opposed to selecting from a list of potential answers
4. **Written Response:** communicate in writing the explanation of the procedure and/or outcome to a math open-ended question

Chapter 2

Literature Review

Math word problems with written responses are increasingly utilized in elementary classrooms to challenge students to higher levels of mathematical understanding. They require students to comprehend the context of the math being presented in narrative form, extract the necessary information from the question to solve the problem, determine the appropriate method to solve, solve the problem and then often explain how the problem was solved. Montague and Bos (as cited in Alter, 2012) contend that students eligible for special education services often perform below their peers in the skill areas utilized in these responses such as reading comprehension, mathematics, and written expression. Therefore, students with disabilities often face challenges when completing written responses questions in math.

Strategies have been created to help students analyze word problems to assist students in their comprehension of the problem. One such strategy known as the C.U.B.E.S. strategy is an acronym where each letter stands for a step that students can follow. The origin of the C.U.B.E.S. strategy is unknown, however this is taught to students in order to give them a systematic way to approach the problem. The 'C' stands for the "**C**ircle the Numbers" coaching students to extract any numbers they will need to solve. 'U' stands for "**U**nderline the question" where students underline the part of the problem that is asking the question or telling them what they need to find. 'B; stand for "**B**oxing important words" where students box words that suggest an operation to use such as 'altogether' which can suggest addition or multiplication or 'gave away' which can suggest subtraction. The 'E' stands for "**E**valuate how to solve the problem and

eliminate any unnecessary information" and 'S' stands for "**S**olve the problem and check". This strategy can be applied to any word problem, but does not assist the students in the performance of the mathematical concepts themselves. Additionally, research on the effective use of the C.U.B.E.S. strategy is not easily found.

Problem-Solving

Problem-solving in mathematics requires students to apply their mathematical understanding at a higher-level of thinking. This can often be a challenge for students with disabilities. For example, students with attentional difficulties and learning disabilities may have difficulty obtaining the mathematical skills necessary to solve word problems. Students who have difficulty with reading comprehension face the challenge of understanding the parts of the problem and what it is asking them to find. Strategies have been created by educators to assist these students in problem-solving.

Token Economy in Conjunction with Problem-Solving Steps

In addition to C.U.B.E.S, other problem-solving approaches exist to provide students with learning disabilities a systematic way to approach word problems. Alter (2012) investigated whether teaching a multistep problem-solving strategy with each step being reinforced with a token economy system would improve students' on-task behavior and ability to problem solve. The problem-solving steps included the following:

1) Read the Problem Aloud

2) Paraphrase
    a) Give important information
    b) Repeat question aloud
    c) What is asked? What am I looking for?

3) Visualize
    a) Draw a diagram

4) State the Problem
    a) I have...I want to find...

5) Hypothesize
    a) If I...then...

6) Estimate
    a) Round the numbers

7) Calculate
    a) Label
    b) Circle

8) Self-check
    a) Check every step
    b) Check calculation
    c) Does the answer make sense?

Participants in this study included three boys from the same class at an alternative school. The primary disability for each student was an emotional and behavioral disorder. All problems were written specifically for this study. A pretest and posttest containing 10 problems was used in the study as well as a daily worksheet which consisted of 20 to 25 problems. For each of these tests and worksheets four strands of the curriculum were utilized including two-digit by one-digit multiplication of whole numbers, division as the inverse of multiplication, algebraic thinking/counting patterns, and identification of fractions. During the intervention, the token system involved students having an index card that was hole punched in order to reinforce on- task behavior. Students received a new index card at the beginning of each session that read “Follow Directions, Try Your Best”. Students were also given a laminated sheet of the eight problem-solving steps in 22-point font. Items used for reinforcement in the token economy system included computer games, a football, a magnetic dartboard, and preferred snacks typically given out by the teacher.

Students were given two pretests prior to completing the baseline. They were then given a daily worksheet with 25 problems in order to determine a baseline. The teacher circulated around the room while the students completed the assessments and read problems aloud as needed but did not provide the students with any verbal praise or prompts or any other assistance in solving the problems. During the intervention phase, the students were instructed on how to use the problem-solving steps through teacher modeling. The students were then able to try the steps on their own with corrective feedback from the instructor. The students were then given reinforcement through the token economy system as they completed each step. Verbal praise was also used alongside punching the student's card. Following the intervention sessions, 51 days after the pretest was given, students were given a posttest. During the posttest students were not given the laminated list of problem-solving steps and did not have a token punch card (Alter 2012).

Problem-solving and on-task behaviors increased when compared to the baseline. The average number of problems completed by each student significantly decreased, however this can be attributed to the time students took to work through the problem solving steps as they solved the problems instead of guessing an answer or simply adding the numbers in the problem (Alter, 2012). The study demonstrated that using problem-solving steps in addition to a token economy is an intervention strategy that can be used to help students eligible for special education.

While strategies such as the C.U.B.E.S strategy and Alter's token system in conjunction with problem-solving can provide students a framework for approaching a word problem or motivate a student to work through the steps, if a student's

understanding of the underlying mathematical concepts is not strong they may still be unable to successfully complete the problem. Students with learning disabilities in mathematics often have difficulty with the understanding of the mathematical concepts themselves. Therefore it is necessary to ensure that the instruction being used to teach the mathematical content is facilitating higher order thinking in math to give students the tools to successfully complete higher level mathematical problems such as word problems, most specifically written response questions. A pedagogical focus has been the role of questioning in the classroom and its ability to increase student learning.

Questioning

As education shifts to a more student-centered approach to learning, new techniques are being developed to increase the student's role in the lesson. Questioning, whether by the teacher or student, and its impacts in the classroom has been a central focus of research studies. Most studies have researched the role of the teacher's questions in the student's learning. Studies have investigated the impact on critical thinking and student confidence, student cognitive ability, higher-order thinking capabilities, and closed versus open-ended questions.

Questioning strategy to elicit classroom discussion. The ability to think critically is understood to be an important skill for students to develop during their time in school. While education traditionally has centered around the transmission of information from teacher to pupil, education has been evolving beyond facts to the teaching of critical thinking. Questioning is one such strategy being implemented in the hopes of increasing students' ability to think critically. One study implemented by Rashid and Qaisar (2016) studied the impact of questioning on students' critical thinking skills in

a fourth grade classroom. In this particular school, teaching was focused on disseminating information to students through lecture and the primary objective was for students to learn factual information. This research study incorporated questioning into one classroom to analyze the effect the questioning strategy had on the students' ability to think critically.

Participants in this study included students from three public school 4th grade classrooms in a public school is Pakistan. These students were eleven years old at the time of the study. Data was collected through video recording and questionnaires filled out by the students before and after implementation of the strategy. The change in students' response to the questionnaire was used to determine the change in critical thinking.

The strategy was implemented in sessions known as "episodes". In these episodes students were posed questions centering around various topics for the given lesson. For example one episode centered around "aero planes". Students were asked questions such as, "Why do cars not fly like airplanes?" and "Why do we use airplanes?". Students then engaged in discussions providing examples and sharing their prior knowledge. Following implementation of an episode, the students were given the post questionnaire. Student responses were scored on a four point scale ranging from weak critical thinking to strong critical thinking. The average critical thinking was only scored as weak for one episode conducted. The results showed that implementing the questioning strategy promoted critical thinking amongst the students. Additionally, it was observed that students' confidence increased by interacting with their classmates and teacher during class activities (Rashid & Qaisar, 2016).

Teacher question complexity. It is not enough for teachers to simply include questions in their lessons in order to promote higher level thinking. Teachers also need to challenge themselves to ask complex questions that challenge students' thinking to new levels. Teachers entering the profession are now often familiar with Bloom's Taxonomy. Bloom's Taxonomy is a model that classifies learning objectives from simple to more complex including remembering, understanding, applying, analyzing, evaluating, and creating. Just as learning objectives have been challenged to increase in complexity, studies have also shown that the complexity of teacher's questions can impact students' cognitive levels.

One study that was conducted by Smart and Marshall in 2012 investigated teacher questioning and its correlation to student cognitive ability. Ten female middle school teachers from two schools, referred to as School A and School B, participated in this study and ranged in teaching experience from 1 to 35 years. Each participant attended a comprehensive professional development program to be trained in inquiry-based instruction and received follow-up training following the PD. The teachers implemented the 4Ex2 Inquiry Model which is a framework for instruction following the sequence Engage, Explore, Explain, and Extend for inquiry-based instruction during this study. The data was gathered through observations throughout the year as the lessons were implemented. The Electronic Quality of Inquiry Protocol was used to measure the quality of the instruction which consists of five evaluated constructs: time, instruction, discourse, curriculum, and assessment. Discourse in particular looks at questioning level, complexity of questions, questioning ecology, communication patterns and classroom interactions (Smart & Marshall, 2012).

The results of this study showed that classroom discourse was directly related to students' cognitive levels. Teachers that engaged their students in higher order thinking questions that required them to explain and justify their thinking performed at a higher cognitive level than students in classrooms where teachers posed factual or procedural questions (Smart & Marshall, 2012). This evidence stressed the importance of teachers incorporating higher level classroom discourse into classroom instruction.

Suchmans' Inquiry Model

Inquiry involves one's pursuit of information through investigation. Inquiry-based education has become emphasized as teachers strive to engage their students as more active participants in their learning. Suchmans' Inquiry Model is one model that has been studied and shown to increase student level of critical thinking through student generation and discussion of questions. One study conducted by Mohamed Alshraideh (2009), investigated the effect of Suchmans' Inquiry Model on critical thinking in college level students. This model consists of four steps. The first step is that "people ask and think when faced with a problem or puzzling situation", the second step is "the analysis of the students' thinking strategies helps them to become conscious of their own thinking", third "students can be taught new strategies which they can add to the strategies they already have" and finally "the skill of questioning and inquiry helps students to learn the natural and experimental analysis of knowledge and give alternate explanations" (Alshraideh, 2009).

In this model students are taught to ask questions based on a problem posed by the teacher. The students then collect, analyze, and discuss data as result of their questioning to solve the problem posed. In this study, 42 students were studied in an

experimental group at AL-Hussien Bin Talal University, while 54 students were in a control group. The experimental group was taught using Suchman's Inquiry Model throughout their course from day one. At the end of implementation of the model, students were given the Watsen-Glaser Critical Thinking Appraisal to assess their level of critical thinking. The test assessed five areas of critical thinking including inferencing, recognition of assumptions, deduction, interpretation, and evaluation of arguments (Alshraideh, 2009, p. 60-61). The students were given a pretest prior to implementation and a post-test.

Results of this study showed that Suchmans' Inquiry Model significantly impacted students' abilities to think critically on all five test areas. Students in the experimental group had a mean score of 36.4 on the post-test while students in the control group had a mean score of 31.4. These findings were similar to other studies involving this inquiry model which found that it successfully elevated student's higher-order thinking capabilities (Alshraideh, 2009). This study provides evidence of positive effects of student-generated questioning strategies.

Open-ended Questions and Mathematical Creativity

Two categories can be used to classify questions: closed and open-ended. Closed questions have one answer such as, 'What is 5x4?'. There is one answer: 20. An open-ended question cannot be answered with 'yes' or 'no' or one response, rather it can have multiple answers. Math problems tend to have one correct answer and therefore mathematics instruction will often consist of a copious amount of closed questions. However, incorporation of open-ended questioning in mathematics instruction allows

students to share their thinking, justify their work, and see the creativity in the variety of ways their peers solve problems.

One study was conducted to analyze a teacher's questions related to the students' responses and mathematical creativity. This study conducted by Mela Aziza (2018) consisted of one female, third grade teacher in the United Kingdom who had a class of 27 third graders aged 7 and 8. Observations and interviews were used to gather data related to teacher questioning and students' responses. An observation was done of one math lesson. The lesson was recorded, notes were taken, and six student work samples were collected. The researchers categorized teacher questions as closed or open-ended and reviewed classroom discourse. Following the observation, the recording and notes were reviewed to generate questions for interviewing the teacher and six students for clarification (Aziza, 2018).

The data collected showed forty-eight questions were posed during the lesson including 26 closed questions and 22 open-ended. Closed questions included, "What is the inverse of 6x7?", "What's double 2?", and "Does it have an angle?". Open-ended questions included, "If the answer is 42, what could the question be?", "Why? Explain to your partner.", and "How can you make sure they are different?" In reviewing students' responses to these questions, mathematical creativity was evident in the variety of correct responses given to open-ended questions. For example, ten different correct solutions were given to one open-ended question where students were asked to generate a question with an answer of 42 (Aziza, 2018). This study demonstrates the value in posing open-ended questions to foster mathematical creativity during classroom discussion of mathematical problem solving.

The Question Formulation Technique

These studies have demonstrated the value of questioning in the classroom, however from the idea that the teacher's role is to ask questions and the student's role is to respond to that question, engaging in discussion and critical thinking. A new technique called the Question Formulation Technique (QFT) was developed by Luz Santana and Dan Rothstein from the Right Question Institute in Lawrence, MA. It was created as a way to teach individuals how to formulate their own questions and by doing so shifts the role of the questioner to the students.

In this technique, the teacher shows the students what is known in the QFT as the "Question Focus". The Question Focus is "a stimulus for jumpstarting student questions" and can be anything such as an image, drawing, video clip, math equation, a statement, etc. as long as it is not a question. This Question Focus is posed at the beginning of the lesson or unit. The students then create a list of questions about the question focus. The QFT has four rules for producing questions

1. Ask as many questions as you can
2. Do not stop to discuss, judge, or answer the questions
3. Write down every question exactly as it is stated
4. Change any statement into a question

After students have listed their questions, students then work to improve their questions by identifying each question as either a closed question (C) or an open-ended question (O). The class will discuss the advantages and disadvantages of both types of questions and then change a closed-ended question to open and vice versa (Rothstein, 2015).

Once questions have been reviewed and improved, the students will prioritize the three questions they perceive as the most important. These questions will be shared with the class who will then discuss why the questions were chosen. The class will also discuss next steps for these questions by deciding how they will used including what information they need to know and what tasks they may need to complete in order to answer them. Questions will then be referred back to throughout instruction.

Following the lesson or unit, students reflect on their work including what they have learned and how they can use what they have learned. This final stage highlights the value of their learning by encouraging its application (Rothstein, 2015).

The Right Question Institute, the organization promoting the QFT, promotes an increase in student engagement, acceleration of knowledge acquisition, formative assessment capabilities, and summative assessment capabilities as the benefit of the QFT. However, very little information exists about the effectiveness of the QFT itself in student learning. When researching its effectiveness, what is found is testimonials from teachers who have implemented the strategy and are claiming positive results such as increased engagement, better student understanding, etc. Many articles also exist sharing tips for using the QFT, examples of its use in the classroom, and encouragement of its implementation (Vicario, 2017-18; Carpenter & Pease, 2012), noted, however, that research providing evidence of its effectiveness is not easily come by. Therefore the purpose of my study is to collect data surrounding the implementation of the technique with students with learning disabilities to determine if the QFT is a viable strategy to increase student achievement in completing open-ended, written responses in mathematics.

Chapter 3

Methodology

Setting

School. This study took place at an upper elementary school in a southern New Jersey school district. This is the only upper elementary school in the district of six total schools. The upper elementary school serves students in grades four through six. Following sixth grade the students' transition to the middle school. In fourth grade, most students remain with their homeroom teacher throughout the entire school day. The exception to this includes students attending an elective or students placed in a resource classroom for math or language arts.

According to the most recent New Jersey Performance Report, this school consists of 872 total students. 53% of the student population is male, while 47% is female. As of 2017, 23% of students were receiving special education services. The majority of students are White, making up 70.6% of the student population. 9.9% of students are Asian, 7.0% are Black, and 6.0% are Hispanic (New Jersey Department of Education, 2017).

Classroom. The classroom where this study took place was a fourth grade classroom. The classroom has two teacher desks and flexible seating options for the students. The co-teachers in the classroom both teach math, language arts, and science together. The class goes to another teacher for social studies for one period every other day. The inclusion teacher travels with them. The number of students fluctuates throughout the day as some students report to other classrooms for math depending if they are in an advanced math class or require a resource room setting. During math, the teachers instruct a class of 22 total students, seven of which have IEPs. The rest of the

school day there are 25 students in the class when everyone is present. This study was conducted during the math period of the day which occurs during first period at 8:15AM to 9:11AM.

Participants

This study contained four participants from the fourth grade inclusion math class. One student is female and three students are male. At the time of the study, three students were nine years old and one student was ten years old. Three of the students are classified with a specific learning disability (SLD) and one student is classified as other health impaired (OHI). All the participants have an IEP in order to meet their individual needs in the classroom. See table 1 for a breakdown of participant data.

Table 1

General Participant Data

Student	Age	Classification
A	9 years old	OHI
B	9 years old	SLD
C	10 years old	SLD
D	9 years old	SLD

Participant 1. Student A is a 9 year old Caucasian male. He is eligible for special education services under other health impaired and is in the inclusion classroom for the entire school day. Student A is an active student who is frequently up out of his seat and often socializes with peers in the classroom both during instruction and independent work time. His attention fluctuates throughout the day and can require redirection to remain on task. Due to his health issues, student A has frequently missed school in the past and been late to school on days when he is not feeling well.

Participant 2. Student B is a 9 year old Caucasian male eligible for special education services under specific learning disability. He remains in the inclusion classroom for the entire school day. Student B is quiet and respectful student. He participates in math more than in other subject areas and tends to demonstrate independence with math procedures at the same rate as his nondisabled peers. The area where student B requires the most support is reading comprehension and written expression. Therefore, word problems and written responses in math are a challenge for student B.

Participant 3. Student C is a 10 year old Caucasian female. She is eligible for special education services under both other health impaired and a specific learning disability. Student C remains in the inclusion classroom for the entire school day. She is a kind and respectful student, but is very quiet and does not participate in class unless prompted. Student C can be unorganized with her materials and is inconsistent when completing homework.

Participant 4. Student D is 9 year old male eligible for special education services under specific learning disability in reading comprehension. This diagnosis affects him

across all academic subjects. He is a sweet and caring student. Student D's behavior is class can vary from day to day. Some days he is willing to complete classwork and other tasks asked of him, other days he is reluctant to complete assignments and can quietly talk back under his breath.

Research Design

This research used experimental research design. This study investigated the effect of the independent variable, the Question Formulation Technique, on the dependent variable, written responses in math. Students have been completing written response questions on each of their summative chapter assessments. The students average scores from the previous tests serve as the baseline. Intervention then occurred throughout three chapters. The Question Formulation Technique was used at the beginning of each chapter and the questions were utilized and referred to throughout the course of the chapter. All other classroom procedures and instruction styles remained the same as prior to intervention. Students then took the summative chapter assessments. The same rubric was used to assess their written responses as prior to intervention.

Procedures

Baseline data was collected by reviewing student's previous written responses from the Chapters 4 and 5 tests and scoring them using the rubric. Topics covered in those chapters included multiplying by a one-digit number and multiplying by a two-digit number. This included 7 questions altogether. The students were then taught the Question Formulation Technique during Chapters 8 and 9. These chapters covered fractions and operations with fractions.

First, the class was taught the procedures and rules for the Question Formulation Technique. Students were told that they would be shown an image momentarily and their job was to create a list of questions about the image called the Question Focus. Students were explained the four rules of the QFT:

1) Ask as many questions as you can
2) Do not stop to discuss, judge, or answer the questions
3) Write down every question exactly as it is stated
4) Change any statement into a question

Students were shown 1 ⅖ in picture form, as a mixed number and as an improper fraction as the Question Focus of the first day of Chapter 8. The class then worked in five groups of four and one group of three to list as many questions as they could about the Question Focus.

Students then worked in their groups to improve their questions by identifying the closed and open-ended questions and rewriting a closed question to open and vice versa. The groups each then prioritized three questions and recorded the questions on a poster to be displayed throughout the chapter. The teacher then facilitated a discussions about the next steps for the questions. The class discussed how they will be looking to answer these questions throughout the chapter and will refer back to them each day to determine which questions they can answer.

At the end of the chapter the students reflected on what they learned in Chapter 8 using the list of questions as their guide. Students responded to the questions: What did you learn in Chapter 8? How can you use the skills you learned in Chapter 8 in your life? Finally, students took the Chapter 8 test which consisted of 3 written response questions.

This process was then repeated with Chapter 9 and Chapter 10. Students were given the Question Focus which was a model of ⅝ total with ⅜ crossed out for Chapter 9 and the fraction 0.52 represented in decimal, fraction, and hundreds grid form for Chapter 10. The QFT was implemented in the exact same manner as Chapter 8 and then students were given the Chapter tests which consisted of 3 written response questions for both Chapter 9 and Chapter 10.

Materials

Written response questions from both tests were scored using the same rubric as was used to determine the baseline (Table 2). The rubric is a holistic rubric on a 0-4 scale. The written response questions from Chapters 3, 4 and 5 that were utilized to determine a baseline are listed in Table 3 and the questions from Chapters 8, 9, and 10 used after intervention are listed in Table 4. This study also required chart paper for each group of students to list their questions.

Table 2

Written Response Rubric

Level	Specific Criteria
4	The student demonstrates a **thorough understanding** of the mathematics concepts and/or procedures embodied in the task. The student has responded correctly to the task, used mathematically sound procedures, and provided clear and complete explanations and interpretations. The response may contain minor flaws that do not detract from the

	demonstration of a thorough understanding.
3	The student demonstrates an **understanding** of the mathematics concepts and/or procedures embodied in the task. The student's response to the task is essentially correct with the mathematical procedures used and the explanations and interpretations provided demonstrating an essential but less than thorough understanding. The response may contain minor errors that reflect inattentive execution of the mathematical procedures or indications of some misunderstanding of the underlying mathematics concepts and/or procedures.
2	The student has demonstrated only a **partial understanding** of the mathematics concepts and/or procedures embodied in the task. Although the student may have used the correct approach to obtaining a solution or may have provided a correct solution, the student's work lacks an essential understanding of the underlying mathematical concepts. The response contains errors related to misunderstanding important aspects of the task, misuse of mathematical procedures, or faulty interpretations of results.
1	The student has demonstrated a **very limited understanding** of the mathematics concepts and/or procedures embodied in the task. The student's response to the task is incomplete and exhibits many flaws. Although the student has addressed some of the conditions of the task, the student reached an inadequate conclusion and/or provided reasoning that was faulty or incomplete. The response exhibits many errors or may be incomplete.
0	The student has provided a **completely incorrect solution** or uninterpretable response, or no response at all.

Table 3

Pre-intervention Baseline Test Questions

Chapter 3 Questions
Explain how to model 3 groups of 6. Write the fact family for the number sentence 3 x 6 = 18.
Why does any number multiplied by 0 equal 0?
Jenny is having trouble solving the problem 2 x 3 x 4. Explain to Jenny how to solve the problem using the Associative Property of Multiplication.
Use the equation 2 x 3 = 6 to describe how multiples and factors are related.
Chapter 4 Test Questions
Estimate the product of 3,562 x 7. (Do NOT find the actual product.) Explain whether the actual product is greater than or less than your estimate.
Explain how to use partial products to multiply 253 x 4. Be sure to solve 253 x 4
Cindy is using the Distributive Property to multiply 67 x 4. She found the answer to be 52. Find and correct her mistake. Then, solve 67 x 4 correctly.
Write a problem multiplying 3 by a four-digit number with a 0 in the hundreds place. Explain how to find the product, then solve.
Chapter 5 Test Questions
Explain the steps you would use to multiply 82 x 47. Use the terms estimate, multiply, partial products, and reasonableness in your response. Underline each term. Be sure to solve, too!
Explain how to multiply 35 x 18 using the Distributive Property. Be sure to solve and find the product!
Lauren is using partial products to multiply 95 x 47. She found the answer to be 1,045. Find and correct her mistake, then solve and find the correct answer.

Table 4

Post-intervention Test Questions

Chapter 8 Test Questions	**Chapter 9 Test Questions**
Complete the equation below. Explain: How did you decide which numbers to use?	Noah spent some of his allowance on Monday. He spent ⅙ of his allowance on Tuesday, and 3/6 on Friday. None of his allowance money is left. What fraction of his allowance money did Noah spend on Monday? Explain how you found your answer.
Write two numbers between 20 and 30 that are both multiples of the same number. What factor do they have in common?	The fourth grade is going on a field trip! There are 5 classes, and each class needs ⅔ of a bus. How many buses are needed for all the classes to go on the field trip? Explain.
Celia used celery, carrots, and tomatoes in a recipe. Use the clues below to find the amount of each ingredient. Use benchmark fractions to compare, and put your final answer in order from least to greatest. • The amounts were ⅖ cup, ¾ cup, and ⅝ cup • There is less celery than tomatoes. • There is less tomatoes than carrots.	Carlson, Becky, and Emma are sharing a pizza that has 12 slices. Carlson ate 3/12 of the pizza. Becky ate 2/12 of the pizza. There are 5 slices left. What fraction of the pizza did Emma eat? Explain how you found your answer.

Dependent Variable

Student achievement. This study was designed to determine the impact the QFT has on student achievement of written responses in mathematics. This was measured by scoring the written responses using the holistic rubric in Table 2. A score of 4 indicates that the student has a thorough understanding of the mathematical concepts and procedures in the task and provided a clear and complete explanation. A score of 3 indicates that the student demonstrated an understanding of the mathematics concepts and procedures embodied in the task. The student's response demonstrated an essential but less than thorough understanding. The response may contain minor errors that reflect inattentive execution of the mathematical procedures. A score of 2 indicates that the student demonstrated a partial understanding of the mathematical concepts and procedures in the task. The student may have used the correct approach to obtaining a solution or may have provided a correct solution, the student's work lacks an essential understanding of the underlying mathematical concepts. A score of 1 indicates that the student has demonstrated a very limited understanding of the mathematics concepts and/or procedures embodied in the task. The student's response to the task is incomplete and exhibits many flaws. Finally, a score of 0 indicates the student has provided a completely incorrect solution or no response at all.

Data Analysis

Data was compiled into a table, formatted as Table 5 below, for the baseline and the intervention. Each participants' data was then used to calculate the mean score. The data from the table was then converted into graphs for a visual display.

Table 5

Baseline Data Analysis

	Student A	Student B	Student C	Student D
Question 4.1				
Question 4.2				
Question 4.3				
Question 4.4				
Question 5.1				
Question 5.2				
Question 5.3				
Mean				

Chapter 4

Results

This study was conducted using an experimental research design with four participants. The independent variable was the implementation of the Question Formulation Technique at the introduction of each chapter of a math textbook. In groups, students formulated questions around a given Question Focus. Each group then selected their top three questions. These questions were compiled and posted in the classroom on chart paper. Throughout the chapter the students referred back to these questions and recorded the answers as they were discovered throughout the chapter. At the end of the chapter, students reflected on their learning in a journal where they recorded what they learned over the course of the chapter. Students then responded to three open-ended, written response questions on the end-of-chapter test. The student's responses were graded using a holistic rubric.

Open-ended Responses

Student written responses to the open-ended questions were assessed using a holistic rubric. The rubric had a scale of 0-4. A score of 4 indicated a thorough understanding. A score of 3 indicated an understanding. A score of indicated 2 a partial understanding. A score of 1 indicated a very limited understanding. A score of 0 indicated a completely incorrect solution. Table 6 provides the mean of the data for each students' response scores for the nine written responses following implementation of the Question Formulation Technique.

Table 6

Written Response Mean

	Student A	Student B	Student C	Student D
Pre-Test Mean	2.8182	3.2727	3	2.2727
Post-Test Mean	3.78	3.89	3.4	2.67
Mean Difference	0.9618	0.6173	0.4	0.3973

Student A is a nine-year old Caucasian male. He is eligible for special education services under other health impaired. Student A's baseline average was 2.818. His overall response average after implementation of the QFT was 3.67, an increase of 0.852. Student B is a 9 year old Caucasian male eligible for special education services under specific learning disability. Student B's baseline average was 3.273. His overall response average after implementation of the QFT was 3.89, an increase of 0.617. Student C is a 10 year old Caucasian female. She is eligible for special education services under both other health impaired and a specific learning disability. Student C's baseline average was 3.0. Her overall response average after implementation of the QFT was 3.4, an increase of 0.4. Student D is 9 year old male eligible for special education services under specific learning disability in reading comprehension. Student D's baseline average was 2.273. His overall response average after implementation of the QFT was 2.67, an increase of 0.397. A graph of each student's response average in comparison to the baseline in presented in Figure 1.

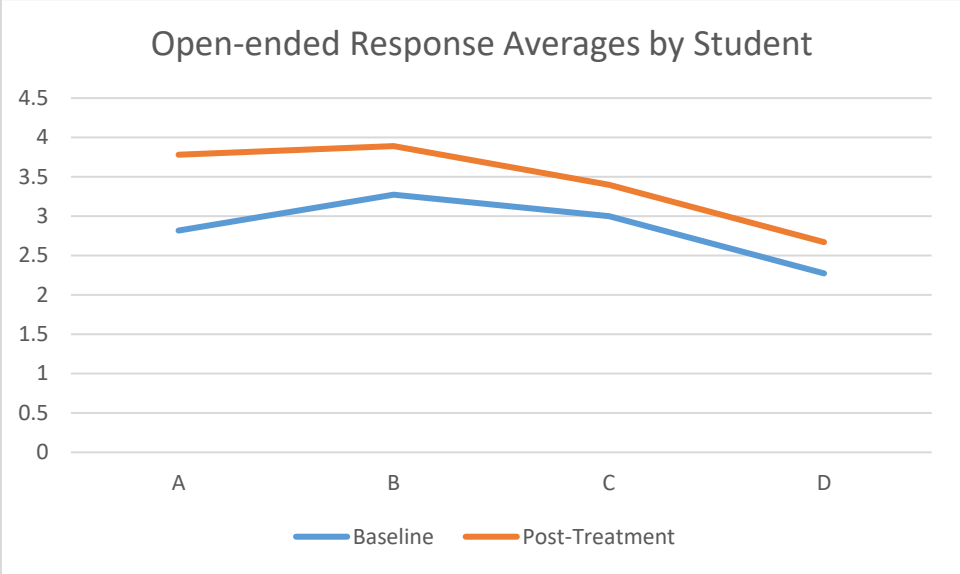

Figure 1. Student Response Averages for Baseline and Post-Treatment

Student A's baseline mean score for the written responses was 2.818. After implementation of the Question Formulation Technique in Chapter 8, Student A's mean score was 3.333, an increase of 0.515. When the QFT was implemented for Chapter 9, the student's mean score was 4, an increase of 1.182 from the baseline. When the final chapter was implemented using the QFT, student A's mean score was 3.778, an increase of 0.962. The overall mean for all three chapters combined was 3.67, an overall increase of 0.852 from the baseline. Student A had the largest increase in their response score average.

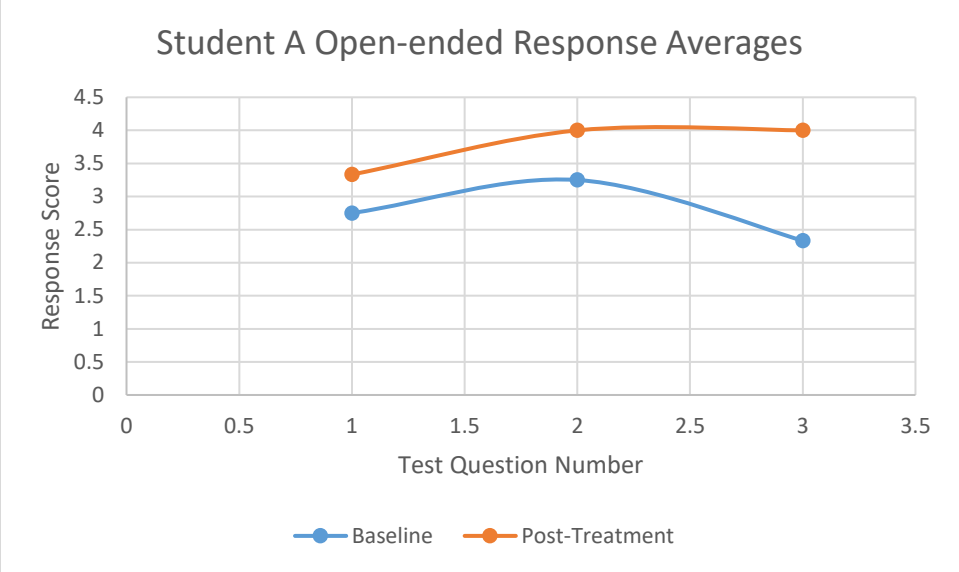

Figure 2. Student A Response Averages for Baseline and Post-Treatment

Student B's baseline mean score for the written responses was 3.273. After implementation of the Question Formulation Technique in Chapter 8, Student B's mean score was 4.0, an increase of 0.727. When the QFT was implemented for Chapter 9, the student's mean score was once again 4.0, an increase of 0.7273 from the baseline. When the final chapter was implemented using the QFT, student B's mean score was 3.667, an increase of 0.394. The overall mean for all three chapters combined was 3.89, an overall increase of 0.617 from the baseline.

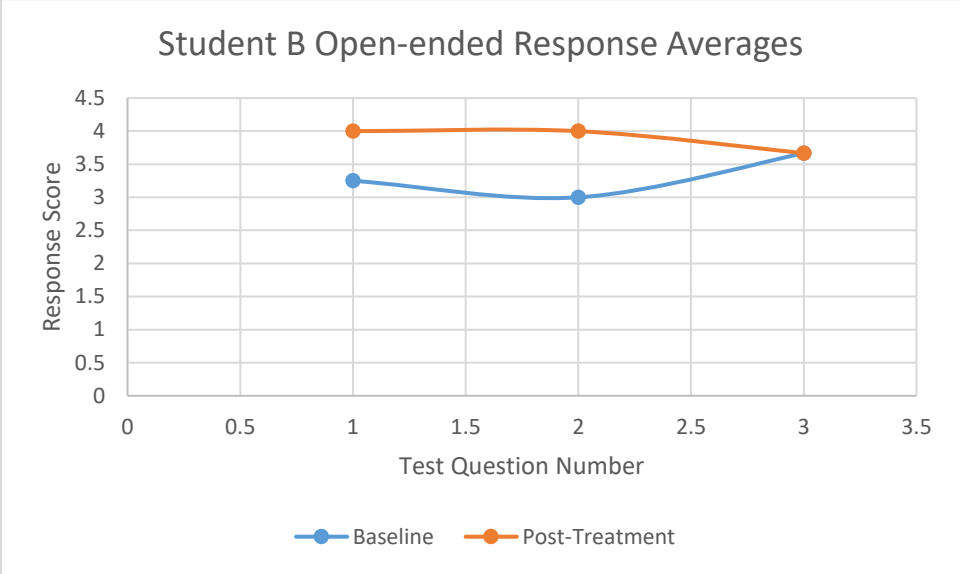

Figure 3. Student B Response Averages for Baseline and Post-Treatment

Student C's baseline mean score for the written responses was 3. After implementation of the Question Formulation Technique in Chapter 8, Student C's mean score was 3, showing no change. When the QFT was implemented for Chapter 9, the student's mean score was 3.333, an increase of 0.333 from the baseline. When the final chapter was implemented using the QFT, student C's mean score was 3.667, an increase of 0.667. The overall mean for all three chapters combined was 3.4, an overall increase of 0.4 from the baseline. Student C did not demonstrate an increase in their response score comparatively to the baseline after the initial round of QFT implementation. After the second and third round, she demonstrated an increase in her written response scores comparative to the baseline.

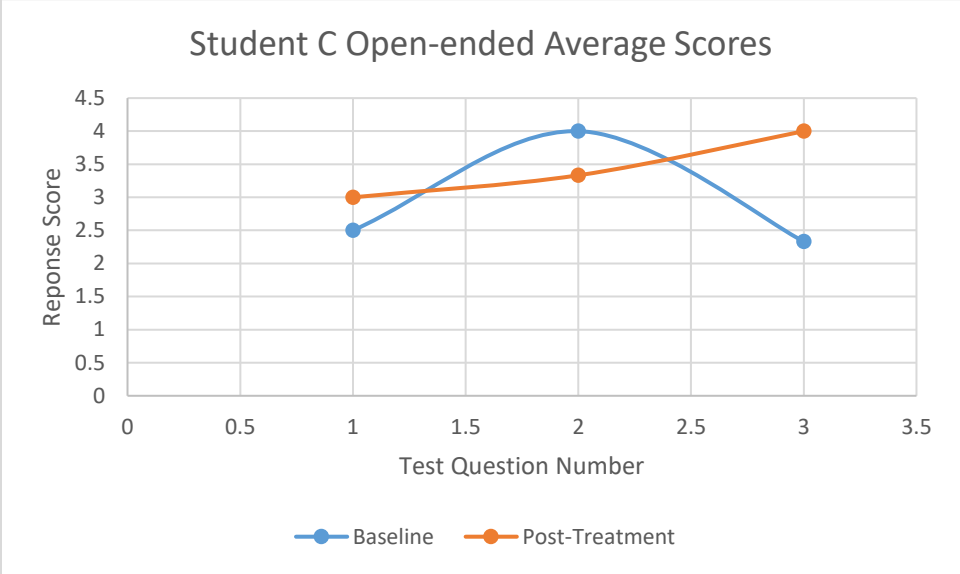

Figure 4. Student C Response Averages for Baseline and Post-Treatment

Student D's baseline mean score for the written responses was 2.273. After implementation of the Question Formulation Technique in Chapter 8, Student D's mean score was 2.333, an increase of 0.06. When the QFT was implemented for Chapter 9, the student's mean score was again 2.333, showing an increase of 0.06 from the baseline. When the final chapter was implemented using the QFT, student D's mean score was 3.333, an increase of 1.06. The overall mean for all three chapters combined was 2.67, an overall increase of 0.397 from the baseline.

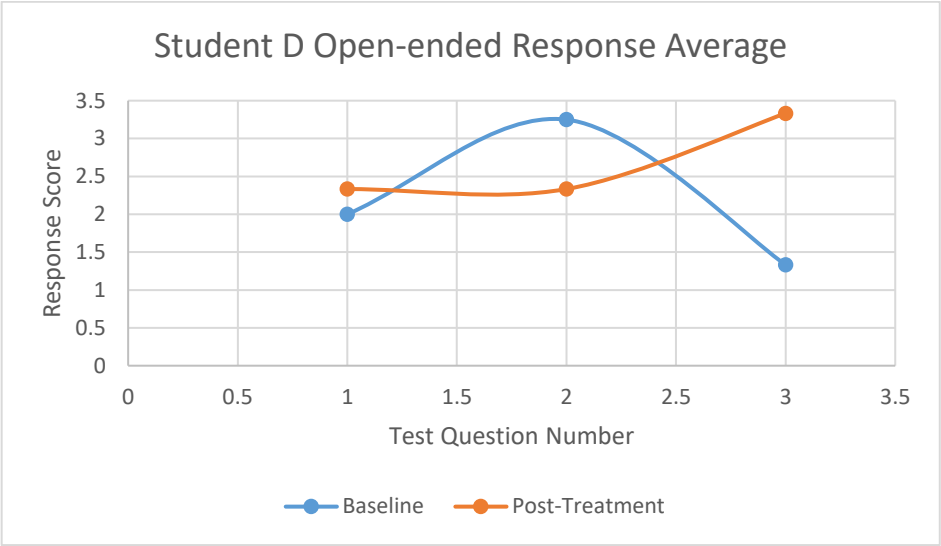

Figure 5. Student D Response Averages for Baseline and Post-Treatment

Chapter 5

Discussion

The purpose of this study was to investigate the impact of the Question Formulation Technique on written response questions in mathematics in an inclusion classroom. This study investigated whether the technique influenced the student's ability to demonstrate a complete and thorough understanding of the mathematical concepts when completing an open-ended prompt. The four participants in this study were eligible for special education services under the categories Specific Learning Disability and Other Health Impaired.

Findings

Three chapter tests were used to determine a baseline score for each of the four participating students. Three chapters of instruction were used during this study. The tests for the corresponding chapter served as the posttest. Each of the four participants achieved an increase in their average written response score. This demonstrates that each student, on average, was able to better demonstrate their understanding of procedures embodied in the tasks and was better able to prove their understanding of the mathematical concepts following training on the Question Formulation technique. Student A began the study with an average ability to demonstrate a partial understanding of mathematical concepts. After treatment, student A's average demonstrated a complete understanding of the concepts. Student B and C began the study in the low 3 range demonstrating a full understanding, however their responses contained flaws, lacked explanation, or demonstrated a misunderstanding. After treatment, Student B and C moved up in the 3 range, improving in their ability to demonstrate their understanding

and completing all portions of the given task. Student D began in the low 2 range showing an average ability to demonstrate only a partial understanding of the mathematical concepts. Post treatment, Student D moved up in the 2 range, showing some improvements, but still only demonstrating a partial understanding on average. Student D had the smallest increase in average score.

Looking at consistency of the response scores, Student B showed the most consistency, demonstrating a thorough understanding of the mathematical concepts on 8 out of 9 questions. Student A and C, both had an outlier with their score for questions 8.2. Student A received a score of 1 demonstrating little to no understanding and Student C earned a score of 2 demonstrating only a partial understanding. This suggests that Student A and C require further instruction in the specific area of factors and multiples as was the procedure embodied in the task. Student A also had an outlier with question 9.2 earning a score of 2 demonstrating only a partial understanding. Therefore, Student A requires additional instruction on converting improper fractions into mixed numbers. Student D had the most inconsistency in response scores. One possible explanation for this is that this student also demonstrates inconsistency in their ability to sustain attention during lessons particularly early in the morning when math occurs. Some days the student is alert and engaged, other days the student has significant difficulty engaging in the lesson.

These results are similar to the findings of Smart and Marshall (2012) that engaging students in higher-level classroom discourse, can have a positive impact on student learning. In Smart and Marshall's study, they found that classroom discourse was directly correlated to students' cognitive levels. This study further supports the idea that engaging student's in classroom discourse can have a positive impact on their

achievement in the class. Another study by Alshraideh (2009) investigated the impact of student generated questions and also found that when students asked questions there was a positive academic impact. Alshraideh utilized Suchman's Inquiry Model to teach students to ask questions and then collect and analyze data surrounding their questions. The students who participated in this study showed evidence of higher levels of critical thinking skills after learning and using this model. Similarly, this study has provided evidence that teaching students to generate questions using the Question Formulation Technique can positively impact their ability to problem solve and demonstrate their understanding on open-ended responses.

Limitations

One limitation of this study was the inability to use the same math topic for the pretest and posttest. As this study was limited to one classroom of students, the technique was implemented and analyzed using a fraction unit, while the baseline was conducted using a multiplication and division unit. This may have impacted the data as students' ability to demonstrate understanding in the written responses may have been influenced by their ability in one particular mathematical area.

Another limitation of this study was student absences. The QFT is largely a whole group technique. Therefore, when a student in the study was absent the rest of the class still completed the technique. The absent participant then had to complete the QFT on their own when they returned. Generating questions on their own could lead to different results than collaborating with classmates and engaging in the whole class discussion.

Finally, the low number of participants is another limitation of this study. This study only included four participants. Further research should be conducted with a larger

sample size to determine if these results can be generalized beyond these individual students.

Implications and Future Research

The results of this study suggest that having students ask questions about what they will be learning, answer those questions as they learn, and reflecting on their learning could have a positive impact on their ability to demonstrate their understanding in math. As demonstrated in previous research, questioning has been shown to increase student cognitive ability and student achievement. This present study suggests the benefit of engaging the students as active questioners alongside the teacher. While this study was only applied to math, the Question Formulation Technique could be applied to any subject area. Future studies should investigate any impact on the QFT in student achievement in other areas.

Conclusion

This study sought an answer to the question: What impact does the Question Formulation Technique have on written response questions in mathematics? After engaging in the QFT, all four participants' average ability to respond to written response questions increased. Therefore, the Question Formulation Technique seems to be an effective option for incorporation into math lessons in inclusion classrooms.

References

Alshraideh, M., PhD. (2009). The effect of suchmans' inquiry model on developing critical thinking skills among university students. *International Journal of Applied Educational Studies, 4*(1), 58-69. Retrieved from http://ezproxy.rowan.edu/login?url=https://search.proquest.com/docview/203204952?accountid=13605

Alter, P. pja3@stmarys-ca.ed. (2012) Helping Students With Emotional and Behavioral Disorders Solve Mathematics Word Problems. *Preventing School Failure*, 56(1), 55-64. https://doi-org.ezproxy.rowan.edu/10.1080/1045988X.565283

Aziza, M. (2018). An analysis of a teacher's questioning related to students' responses and mathematical creativity in an elementary school in the UK. *International Electronic Journal of Elementary Education, 10*(4), 475-487. doi:http://dx.doi.org/10.26822/iejee.2018438138

Carpenter, J.P.I. jcarpenter13@elon.ed., & Pease, J.S. (2012). Sharing the learning. *Phi Delta Kappan*, 94(2), 36-41. Retrieved from https://search.ebscohost.com.ezproxy.rowan.edu/login.aspx?direct=true&db=eft&AN=82329083&site=ehost-live

Rashid, S. profsmalik@yahoo. co., & Qaisar, S. qaisarshahzada@yahoo. co. (2016). Developing Critical Thinking through Questioning Strategy among Fourth Grade Students. *Bulletin of Education & Research, 38*(2), 153–168. Retrieved from http://search.ebscohost.com.ezproxy.rowan.edu/login.aspx?direct=true&db=eft&AN=122425013&site=ehost-live

Rothstein, D. dan@rightquestion. or., Santana, L. luz@rightquestion. or., & Minigan A. P. Andrew. minigan@rightquestion. or. (2015). Making Questions flow. *Educational Leadership*, 73(1), 70-75. Retrieved from http://search.ebscohost.com.ezproxy.rowan.edu/login.aspx?direct=true&db=eft&AN=110257823&site=ehost-live

Smart, J. jsmart25@gmail. co., & Marshall, J. marsha9@clemson. ed. (2013). Interactions Between Classroom Discourse, Teacher Questioning, and Student Cognitive Engagement in Middle School Science. *Journal of Science Teacher Education, 24*(2), 249–267. https://doi-org.ezproxy.rowan.edu/10.1007/s10972-012-9297-9

Vicario, R. (2017). What’s the Question? Promoting Inquiry-Driven Instruction. *Social Studies Review, 56,* 39-43. Retrieved from http://search.ebscohost.com.ezproxy.rowan.edu/login.aspx?direct=true&db=eft&AN=130132566&site=ehost-live