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# A MIXED-METHOD CASE STUDY OF THE EFFECTS OF QUESTION FORMULATION TECHNIQUE ON CLASSROOM ENGAGEMENT IN A SECONDARY EARTH SCIENCE CLASSROOM AND TEACHERS' PERCEPTIONS OF THIS SHIFT

Kristen Mantione Cummings

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**ABSTRACT**

A MIXED-METHOD CASE STUDY OF THE EFFECTS OF QUESTION FORMULATION TECHNIQUE ON CLASSROOM ENGAGEMENT IN A SECONDARY EARTH SCIENCE CLASSROOM AND TEACHERS' PERCEPTIONS OF THIS SHIFT

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The purpose of this study was to investigate the effect on classroom engagement of question formulation technique (QFT), which teaches students how to produce, improve, and prioritize their own questions. This study took place at a medium-sized suburban high school between September 2018 and May 2019. The sample included 263 students (53.7% male and 46.3% female) from twelve earth science classes taught by five different teachers; 80.5% were freshmen, 6.7% were sophomores, 10.1% were juniors, and 2.7% were seniors. Students completed the Classroom Engagement Inventory (CEI) before and after the intervention. The CEI is a classroom-level survey that uses self-reporting to measure multiple dimensions of engagement: affective engagement, behavioral engagement, cognitive engagement, and disengagement. Students rated each of the CEI's 24 statements on a 5-point scale that ranged from *every day* (1) to *never* (5). Each student's total engagement was the sum of the students' ratings of the 24 statements. At the end of the study a paired-sample *t* assessed indicated significant differences in the means for total engagement between the beginning and end of the year. Themes emerged from hand coding of an open-ended question added to the posttest CEI. The themes indicated that 71% of students found QFT to be a useful tool for classroom engagement. Semistructured interviews conducted with the teachers and analyzed using

Guskey's five critical levels of professional development indicated that teachers found the professional development to be successful. These findings can help with the design of future studies that evaluate classroom practices that increase student classroom engagement. The findings can also assist with the planning of professional development that accompanies these practices.

## DEDICATION

This has been a long, demanding journey that could not have been possible without the support of my family, who encouraged me to go after my dream of a doctorate. I dedicate this work to my husband, Brian, who spent countless nights and weekends chauffeuring our children from one activity to another, taking care of the laundry, cleaning the house, and cooking dinner. He selflessly pushed me out of the house to work on my dissertation, knowing that I would not accomplish much if I stayed home with kids running around. I dedicate this work to my mother and father, Kathy and John, who provided loving support, who have always insisted that I can do anything I set my mind to, and who taught me never to use anything as an excuse to stop me from achieving my goals. Your encouragement, throughout my life, to go after what I wanted has driven me to succeed. You have provided such a continuous example of what can be accomplished through love, determination, and self-belief. I dedicate this work to my mother- and father-in-law, Arline and Don, who have also helped our family during these hectic times and given me unconditional love and support throughout this process. Finally, I dedicate this work to our children, Aidan, Ava, Lilah, Gabriella, and Liam, who spent 3 years watching me leave to go to school or write, and who always gave me encouragement to reach my goals. I hope you witnessed determination and grit that you will model throughout your life as you seek to reach whatever goals you set for yourself. You can do whatever you set your mind and heart to, so keep yourself open to inspiration as you grow up and venture out into the world.

## ACKNOWLEDGEMENTS

Thank you to Dr. Anthony Annunziato, my mentor, for providing continual guidance and direction throughout this challenging process. Even though you have accused me of being a "bad penny," your welcoming demeanor (once I could pin you down) always put me at ease when we conferenced.

I would also like to acknowledge the members of my committee, Dr. Richard Bernato and Dr. John Campbell. Your insights into how to conduct research and your understanding of the existing body of research were humbling and much appreciated. Working with you has been a great privilege.

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# Chapter 1: Introduction

> My investment of time, as an educator, in my judgment, is best served teaching people how to think about the world around them. Teach them how to pose a question. How to judge whether one thing is true versus the other.
>
> —Neil deGrasse Tyson, *Source Unknown*

The National Research Council (2012), in *A Framework for K–12 Science Education*, affirmed that "the learning experiences provided for students should engage them with fundamental questions about the world and with how scientists have investigated and found answers to those questions" (p. 9). The six guiding assumptions of the framework are that children are born investigators, teaching should focus on core ideas and practices, understanding of science concepts develops over time, science and engineering require both knowledge and practice, students should connect their interests and experiences, and school should promote equity.

The Next Generation Science Standards (NGSS, 2019) developed from this framework. The NGSS have three dimensions: science and engineering practices, crosscutting concepts, and disciplinary core ideas. The science and engineering practices are representative of the skills scientists and engineers use every day in their work to figure out phenomena or design solutions to problems. The crosscutting concepts tie together the fields of science and engineering and highlight their commonalities. Finally, the disciplinary core ideas are what people think of as traditional content that students need to understand. All three dimensions progress in their sophistication from kindergarten through 12$^{th}$ grade (K–12). A significant change with these new standards was the expectation that students will use the dimensions to learn. This was a significant culture shift for some classrooms, because the emphasis moved from the teacher and his or her content-related teaching practices to helping students become more independent.

In the NGSS (2019), the use of phenomena is a critical component of students learning to be scientists and engineers. A phenomenon is something natural that occurs in the world. Scientists apply their knowledge of science and the observations they make to predict or explain phenomena. Engineers try to design solutions that arise from phenomena. Phenomena help to ground learning in real life, to shift learning from finding out to figuring out, and to teach students how to transfer knowledge to novel situations.

This research concentrates on the first science practice, asking questions. Students need to be able to ask questions when presented with a phenomenon to figure out what is happening in the world around them. As Berger (2014) stated, "Knowing the answers will help you in school. Knowing how to question will help you in life" (p. 179). When students begin to ask questions about life, the questioning stimulates curiosity, which can lead to an increase in engagement.

Student engagement is a factor in academic success (Chase, Hilliard, Geldhof, Warren, & Lerner, 2014). Engagement is not fixed and can be influenced by the types of experiences students have in the classroom (Malloy, Parsons, & Parsons, 2013). Engagement can be defined in terms of school engagement or classroom engagement. School engagement refers to how connected a student feels to the building; classroom engagement is how connected a student feels to a class (Z. Wang, Bergin, & Bergin, 2014). This distinction is necessary because a student can enjoy coming to school to socialize with his or her friends and to participate in school events while not enjoying participating in class. Conversely, a student may feel connected to academics but not to school culture. For this research, the researcher examined engagement through the lens of affective, behavioral, and cognitive engagement, as defined by Fredricks, Blumenfeld, and Paris (2004). Affective engagement refers to a sense of belonging in the classroom and interest in, or curiosity about, concepts or tasks. Behavioral engagement involves both time on task and active participation. Cognitive engagement includes perseverance, metacognition, and self-regulation (Parsons, Newland, & Parsons, 2014).

Researchers have found that academic engagement decreases as students move from middle school to high school (Fredricks et al., 2004). Additionally, students ask fewer questions as they get older (National Assessment of Educational Progress, 2011). The question formulation technique (QFT) is a research-based protocol designed to help students learn how to produce their own questions, improve them, and strategize about how to use them (Rothstein & Santana, 2011). QFT is not a program: It is one technique that can be used by teachers to help show their students how to formulate questions. QFT helps students move from being passive receivers of information to being active seekers of knowledge (Rothstein, Santana, & Minigan, 2015). Through the QFT process, students are taught to think divergently, convergently, and metacognitively. Increasing intellectual curiosity can lead to increased student engagement. These ideas prompted the question: Would teaching students how to ask questions in a safe and nonjudgmental environment increase their interest in learning and, therefore, increase engagement?

If QFT influences engagement, collection of data from students is needed to assess its impact on engagement. The Classroom Engagement Inventory (CEI) created by Z. Wang et al. (2014) is a 24-item questionnaire that uses self-reporting to measure multiple dimensions of engagement: affective engagement, behavioral compliance engagement, behavioral effortful engagement, cognitive engagement, and disengagement. The inventory's authors designed it to measure engagement on the classroom level rather than the school level. Z. Wang et al. (2014) wanted to create a survey tool for the purposes of

1. evaluating the effectiveness of an intervention enacted at the classroom level;
2. providing feedback to teachers regarding student perceptions of their classrooms;
3. investigating what teachers can do in the classroom to improve engagement; and
4. investigating the link between engagement and learning in specific classes.

The researcher chose this tool because it could gauge the effectiveness of QFT for increasing student engagement at the classroom level. The researcher administered the CEI before and after the QFT intervention to determine whether teaching students how to ask questions increased their engagement in class.

When providing professional development, feedback from teachers is critical for evaluating its overall effectiveness. The researcher selected Guskey's (1995) professional development evaluation model because of its direct approach. The model provides an in-depth five-level evaluation rubric for professional development in education. The model is applicable to evaluation of both the short-term and long-term effects of professional development training, beginning in the training and ending in participants' classrooms (Guskey, 2002). Each level of evaluation builds on the previous level by posing more focused questions and addressing higher order outcomes. For example, Level 1 addresses participants' reaction to the training. Level 2 addresses participants' learning from the training. Level 3 addresses degree of organizational support and organizational change in terms of policy improvements, resource allocation, and difference in organizational climate as a result of the training. Level 4 assesses participants' use of the new knowledge and skills in an appropriate work setting. Finally, Level 5 evaluates changes in student learning outcomes. This evaluation system, coupled with the CIE, should provide evidence of both student and teacher improvement after trainings for QFT and New York State Science Learning Standards (NYSSLS).

**Problem Statement**

The onset of increased testing and the survival mechanism of teaching to the test has reduced focus on the constructivist approach to teaching. Shifting from the teacher-centered classroom to the student-centered classroom is pedagogical change. The new science standards have allowed teachers to refocus their energy on an inquiry-based classroom.

To what extent does implementing the new science standards, shifting to a student-centered classroom, and teaching students how to question phenomena impact student engagement? As teachers go through these shifts, is the professional development provided to them successful when judged using Guskey's (2000) five critical levels of professional development evaluation?

**Statement of Purpose**

The purpose of the study was to analyze whether teaching students to ask their own questions about phenomena increases student engagement. The results of this study can help district and building leaders create professional development plans that support teachers as they learn strategies to make students more independent learners. The researcher designed the study to examine both students' classroom engagement level and teachers' perceptions of student engagement in the classroom as the teachers shifted their pedagogy to meet the new NYSSLS. Throughout this study, the researcher examined the use of QFT to increase engagement with the aim of better informing future studies and providing suggestions regarding specific tools for evaluating the effectiveness of interventions on classroom engagement. Additionally, the researcher examined professional development with the aim of making suggestions regarding continuing professional development needed during implementation of the new science learning standards.

**Research Questions**

Research Question 1 (RQ1) asked, Does teaching students how to ask questions through QFT increase total classroom engagement? The null hypothesis, $H_{0,}$ was that there is no difference in classroom engagement based upon the time of test (pretest versus posttest). The alternative hypothesis, $H_1$, was that there is a difference in classroom engagement based upon the time of test (pretest versus posttest).

Research Question 2 (RQ2) asked, Is there a difference between affective, behavioral, and cognitive engagement as students become more proficient in QFT?

The null hypothesis, $H_0$, was that there is no difference between affective, behavioral, and cognitive engagement based upon the time of test (pretest versus posttest). The alternative hypothesis, $H_1$, was that there is a difference between affective, behavioral, and cognitive engagement based upon the time of test (pretest versus posttest).

Research Question 3 (RQ3) asked, Do teachers notice a difference in classroom engagement from the beginning to the end of the year after shifting their classroom practices? Do teachers' perceptions of classroom engagement align to the level of students' perceived usefulness of QFT as an engagement tool?

Research Question 4 (RQ4) asked, Do teachers feel that the QFT professional development provided to them is valuable based on the five critical levels of professional development evaluation?

**Overview of Methodology**

The researcher used a descriptive case study methodology to conduct this research. Yin (1981) noted that a researcher conducting a descriptive case study strives to document the procedures of a particular event or events. This study relied on an explanatory sequential mixed method design and included qualitative data from a student survey of classroom engagement administered in September and June of one school year. These data will drove the questions for semistructured interviews of earth science teachers who had been incorporating QFT and phenomena-driven teaching into their methodologies. Other data collected throughout the study were nonparticipant classroom observations of instructional methods, student behaviors, and responses of students when asked about QFT in their classrooms.

**Rationale and Significance**

The NGSS were built upon a vision of science education outlined by the *Framework for K-12 Science Education* and published by the National Academies' National Research Council in in 2012. In 2016, New York State adopted these standards, with a few small changes to the disciplinary core ideas, as the NYSSLS. At the time of writing, New York was in Phase 1, raising awareness and building capacity. To build capacity, schools need to shift to inquiry-based learning that focuses on students generating questions used to investigate phenomena. The first step is to teach students how to ask questions; QFT is a protocol to help teachers help students ask questions. The next step is to ensure the approaches are working for both students and teachers. If they are not, adjustments are needed before moving into Phase 2, transition and implementation. See Figure 1.

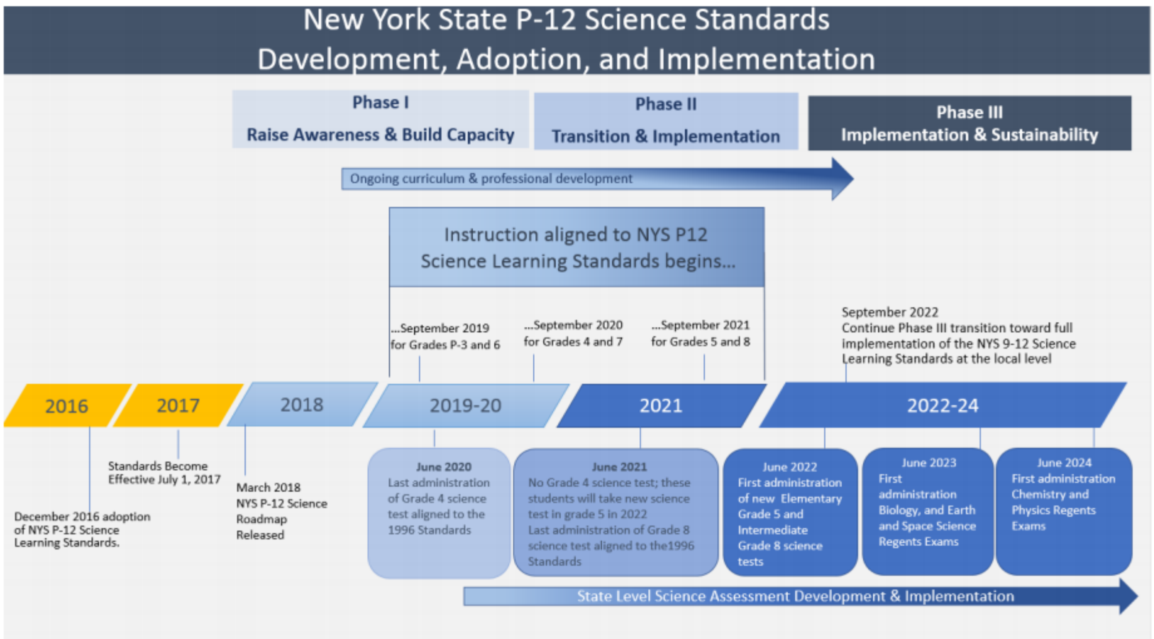

*Figure 1*. Roadmap and timeline of implementation. From *New York State P–12 Science Standards Development, Adoption, and Implementation* (p. 1), by the New York State Department of Education, 2016, retrieved from http://www.nysed.gov/common/nysed/files/programs/curriculum-instruction/science-timeline.pdf.

**Role of Researcher**

The researcher served as the immediate supervisor of the teachers who participated in this research. The researcher created and delivered the QFT training to the teachers. The researcher, along with a professional developer, also educated the teachers about the changes in the new NYSSLS, an adaptation of the NGSS. The teachers administered the student survey, the results of which the researcher analyzed. The researcher collected and coded all the classroom observational data throughout the year.

## Researcher Assumptions

Inquiry-based teaching is necessary not only to teach science but also to develop students capable of transferring the skills they learn to life beyond school. Shifting a classroom from teacher-led questioning to student-led questioning activates curiosity and increases student engagement. Teachers might feel pushback from students and parents, because this approach to teaching represents a shift in culture and differs from the way most parents learned when they were in school.

## Definition of Key Terminology

*Question formulation technique* (QFT) is a protocol designed to teach students how to ask their own questions and strategize about how to use them. It consists of six steps: The teacher designs a question focus, then students produce questions, work with closed-ended and open-ended questions, prioritize questions, plan next steps, and reflect (Rothstein & Santana, 2014).

*Next Generation Science Standards* (NGSS, 2019) are K–12 science content standards. Standards set expectations for what students should know and be able to do. The NGSS identify scientific and engineering practices, crosscutting concepts, and core ideas in science that all K–12 students should master to prepare for success in college and 21st-century careers.

*New York State Science Learning Standards* (NYSSLS) are New York State's adaptation of the NGSS, which add prekindergarten standards and a few other standards throughout the grade levels.

*Phenomenon*: an observable event. In the science classroom, a carefully chosen phenomenon can drive student inquiry. Phenomena add relevance to the science classroom by showing students science in their own world. A good phenomenon is observable, interesting, complex, and aligned to the appropriate standard (Anderson, 2012).

*Cognitive engagement* includes perseverance and the use of metacognitive and self-regulated strategies (Parsons et al., 2014, p. 24).

*Affective engagement* includes a sense of belonging in the classroom and an interest in, curiosity about, or enthusiasm for specific topics or tasks (Fredricks et al., 2011).

*Behavioral engagement* includes time on task and active participation on classroom activities (Parsons et al., 2014).

*Emotional engagement* is often interchangeable with affective engagement and includes a student's affective reaction to tasks, often operationalized to include emotions such as interest (curiosity), boredom, happiness, sadness, and anxiety (Fredricks et al., 2004).

*Classroom engagement* is active involvement by students in classroom learning activities (Z. Wang et al., 2014).

*School engagement* is the extent to which students are involved in, attached to, and committed to the academic and social activities in school (Li & Lerner, 2013).

*Classroom Engagement Inventory* (CEI) measures psychological (cognitive), behavioral, and affective engagement at the classroom level (M.-T. Wang & Eccles, 2012).

*Curiosity* is interest in learning more and the willingness to explore the unknown, embrace novelty, and accept uncertainty (Hulme, Green, & Ladd, 2013).

# Chapter 2: Literature Review

> The experience of learning science and engineering should therefore develop students' ability to ask—and indeed, encourage them to ask—well formulated questions that can be investigated empirically. Students also need to recognize the distinction between questions that can be answered empirically and those that are answerable only in other domains of knowledge or human experience. (National Research Council, 2012, p. 55)

## Introduction

This literature review introduces the theoretical and conceptual frameworks. The review begins with background information on classroom engagement and defines the multidimensional construct examined through this study. The review continues with examination of the empirical evidence surrounding engagement, constructivism, student-centered learning, the history of questioning, and QFT and its possible contribution to student engagement.

## Theoretical Framework

Guskey (1982) investigated the influence of changes in teachers' instructional effectiveness on the relationship between their expectations for students' performance and students' achievement outcomes. This study included 44 intermediate teachers at the high school level from two metropolitan school systems. The teachers volunteered to receive professional development regarding mastery-learning instructional strategies and received compensation for their time. All teachers had at least 3 years of experience, and 24 men and 20 women participated in the study. In the semester immediately following the training, the teachers agreed to teach two of the same classes at the same grade level, using one as a control and employing the mastery-learning format in the other. The students in the mastery class received specific feedback and support to help them correct their misunderstandings, and they then had an opportunity to retake the quiz in another form. The control group received neither the feedback nor the opportunity to retest.

At the beginning and end of the semester, all teachers categorized their students into one of five groups of academic potential ranging from highest (1) to lowest (5). The author compared the ratings, course grades, and course examination scores to determine the change in teachers' instructional effectiveness. The variances of course grades and examination scores were lower in the mastery class than in the control group. The author believed the change in teacher effectiveness would influence the relationship between teacher expectations and student performance: "It is probable that as teachers become more successful in enhancing the learning of students, they have greater difficulty categorizing students by such characteristics as achievement potential" (Guskey, 1982, p. 348). However, Guskey (1982) found that "under more effective instructional conditions teachers may interact similarly with high and low-expectancy students, provide similar types of praise for each, provide similar types of feedback to each, and make comparable demands for work effort of each" (p. 348). In other words, teachers who experienced positive change in their instructional practices had a harder time initially categorizing students' academic potential because all students benefitted from their change in practice. The recommendations for future research were to determine whether teachers view students differently under more effective instructional conditions.

Guskey (1984b) studied what happens to teachers when they adopt more effective instructional strategies. He wanted to explore the possible influence of positive change in instructional practices on affective characteristics of teachers. As in his previous studies, the author used mastery-learning strategies in professional development but did not specifically examine student achievement. Teachers volunteered to be part of the mastery learning in service and received minimal compensation. The distribution of volunteers over two metropolitan school districts allowed 52 teachers to participate in the workshop, and the remaining 65 made up as the control group. Each teacher had a minimum of 3 years' experience teaching in an intermediate or high school in language arts, mathematics, science, social studies, or foreign languages.

All 117 participants completed a three-part questionnaire developed by the author. The first part is the Responsibility for Student Achievement Scale, which assesses teachers' beliefs regarding their own control of factors influencing the academic successes and failures of their students. The second part assesses affect toward teaching, including how much teachers like teaching and how positively or negatively they feel about various aspects of teaching. The third part assesses teaching self-concept; it indicates teachers' feelings in relation to behaviors or characteristics relevant to their teaching.

Guskey (1984a) hypothesized that teachers would assume more responsibility for student outcomes, enjoy teaching more, and have greater confidence in their abilities. The author used a multivariate analysis of variance to compare the pretest and posttest results from the mastery group and the control group. He found that

> teachers who became more effective in their teaching tended to accept increased responsibility for the learning outcomes of their students and tended to become more positive in their attitudes toward teaching. At the same time, however, these teachers expressed diminished confidence in their teaching abilities. (Guskey, 1984a, p. 253)

In analyzing these results, Guskey (1984a) believed the decline was caused by the reality that "these teachers probably felt that the high degree of confidence in their teaching abilities they had expressed earlier was perhaps misgiven" (p. 254). The findings presented so far begin to give insight into teacher change.

As in his earlier studies, Guskey (1985) examined whether staff development influenced teachers' perception of their effective teaching practices and, therefore, explain their effectiveness differently. The subjects in this study consisted of 96 intermediate and high school teachers from an urban school district, 46 trained in mastery-learning technique and 50 who served as controls. The author conducted a pretest and posttest analysis consisting of a survey that used 5-point Likert scales. Ten statements related to personality characteristics, and another 10 related to teaching behaviors. The author used a multivariate analysis of variance to see whether the two groups differed in a statistically significant way.

The teachers who had received the mastery-learning training felt the behavioral aspects of their teaching methods were more important than personality factors. Guskey (1985) said:

> Personality factors tend to be very stable among adults and in most cases are highly resistant to change. Teachers who explain their effectiveness in the classroom primarily in terms of personality factors are thus likely to view the prospects of change or improvement rather pessimistically. Such teachers would probably be reluctant to try new instructional practices and would undoubtedly need extensive help and guidance in order to successfully implement these practices in the classroom. (p. 380)

These findings have important implications in professional development, because teachers' behavior is easier to change than their personalities.

Guskey (1986, 2002, 2009) explained that, in research, the order of change during professional development is attitudes and beliefs, then teaching practices and behaviors, then student learning outcomes and results. However, experience suggested a different pattern (Figure 2).

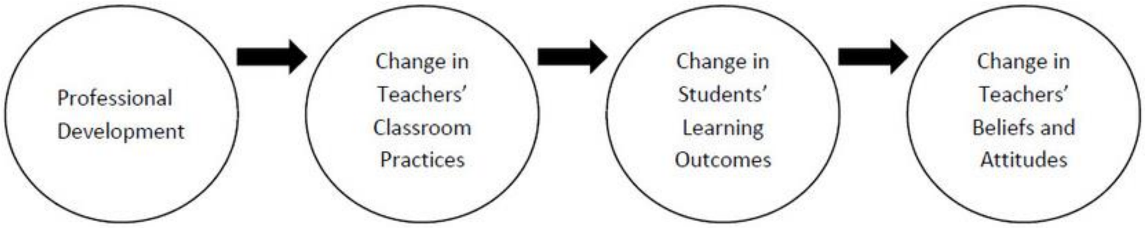


*Figure 2.* A model of the process of teacher change. From "Staff development and the process of teacher change," by T. R. Guskey, 1986, *Educational Researcher, 15*, p. 7.

Figure 2 illustrates that a change in teachers' beliefs and attitudes does not come about until the teachers see an improvement of student learning: "Therefore, to be effective, a staff development program must offer teachers practical ideas that can be efficiently used to directly enhance learning outcomes in students" (Guskey, 1986, p. 6). Guskey (1986) suggested that most professional development programs fail because professional developers do not take into account what motivates teachers to engage in professional development and the process by which change in teachers typically occurs.

Effective professional development requires building into the process follow-up needs; otherwise, teachers have no time to process and reflect on the successes of their work and how it has affected students. Without this process, attitudes and beliefs cannot change; only experience can change attitudes and beliefs. Guskey (2002) further explained that the magnitude of change in student learning is directly related to the magnitude of the change in attitudes and beliefs. The order of change also holds true for students: Once they feel success in the classroom, they become more motivated. As a leader, the first step toward making any sort of lasting change is to have teachers feel the shift in student learning because of their new practices. Three principles stem from this model outlined by Guskey (2002):

1. Recognize that teacher change is a gradual and difficult process for teachers.
2. Ensure that teachers receive regular feedback on student learning progress.

3. Provide continued follow-up, support, and pressure (to initiate change). Administrators should take the synthesis of Guskey's research and plan systematic opportunities for teachers to attend professional development, apply it in the classroom, and have support and time to reflect on the new practices both internally and with other teachers.

**Student Engagement**

Parsons et al. (2014) addressed the complexities of student engagement and discussed three dimensions of student engagement. In their article, they provided an overview of the ABCs of engagement: affective, behavioral, and cognitive engagement. Affective engagement refers to a sense of belonging in the classroom and interest in, or curiosity about, concepts or tasks. Behavioral engagement involves both time on-task and active participation. Cognitive engagement includes perseverance, metacognition, and self-regulation. By being aware of these dimensions, teachers can adjust their lessons to increase engagement. The authors also summarized the spectrum of engagement from high to low and ways to measure student engagement from the student, teacher, and observational perspective.

Fredricks et al. (2004) defined engagement as a multidimensional construct that includes behavioral, emotional, and cognitive engagement. Behavioral engagement includes positive classroom conduct and the absence of disruptive behaviors, involvement in academic tasks, and participation is school-related activities outside the classroom (Fredricks et al., 2004). Emotional engagement (which is similar to affective engagement) includes affective behaviors in the classroom such as interest, boredom, happiness, and anxiety. Finally, cognitive engagement includes intellectual investment in what is being learned and perseverance to work through difficult challenges. Fredricks et al. (2004) summarized their research by explaining that “engagement is associated with positive academic outcomes, including persistence in school; and it is higher in classrooms with supportive teachers and peers, challenging and authentic tasks, opportunities for choice, and sufficient structure” (p. 87). However, further research is needed to create specific interventions to help student engagement.

Freiberg (1996) discussed the need to make students citizens of their schools rather than tourists in them. Students need to be invested in their education and active participants in learning rather than passive listeners of lectures by so-called content experts. Yonezawa, Jones, and Joselowsky (2009) claimed that young people must be treated as active participants in educational institutions to keep students engaged in school. Researchers have found that student engagement is a key factor not only in academic achievement but also for preventing school burnout, alienation, boredom, dropout rates, and discipline problems (Fredricks et al., 2004). Klem and Connell (2004) suggested that focusing first on increasing student engagement—instead of on improving test scores—can foster greater gains in students’ academic, social, emotional, and behavioral achievement.

Clearly defining and measuring engagement is difficult. Harris (2008) explained that 50 years ago, educators measured engagement by class participation and time on task. The primary focus was on academic or cognitive engagement. Judging engagement by time on task is not a good measure, because students can comply and go through the motions of school yet not be cognitively engaged: “Students cannot simply go through the motions of school if they are to learn and retain information and be able to apply it critically in new contexts" (Yonezawa et al., 2009, p. 192). Fredricks et al. (2004) advocated not only moving away from a unidimensional view of engagement but also eliminating the linear interpretation of the multidimensional phenomenon of engagement.

According to Marks (2000), authentic instructional work contributes strongly to the engagement of students. Authentic instructional work consists of students answering interesting questions, solving new problems, digging deeply into understanding single topics, applying the subject to problems and situations in life outside school, and discussing ideas about the subject with the teacher or other students (Marks, 2000, p. 158). The author's sample consisted of 3,669 students from 24 elementary, middle, and high school classes. The author chose six core classes from each of the 24 schools: a social studies class and a mathematics class from each of Grades 5, 8, and 10. The author chose these classes based on two criteria: One teacher from each subject was part of the schools' efforts to restructure the schools for better student experiences, and the classes represented a heterogenous grouping of students. The author used a three-level hierarchical linear model to investigate the interactions of sex, ethnicity, prior achievement, socioeconomic status, grade point average, alienation, authentic instructional work, school support, classroom support, parental involvement on personal background, and orientation toward school. The author explored three research questions, but the second question is most applicable to the current study on classroom engagement:

> To what extent do school initiatives to improve students' learning (namely, providing authentic instructional work, providing a socially supportive environment for learning, involving parents with their children's schooling) counter the influence of personal background and orientation toward school on students' engagement in instructional activity? To what extent are the estimated influences on engagement consistent for students in elementary, middle, and high schools? (p. 160)

Marks (2000) found authentic instructional work is a powerful contributor to engagement for elementary, middle, and high school students: "The effect enlarges somewhat as student grade level becomes higher" (p. 169). The investigation provided insight into the importance of structuring school reform efforts around student outcomes in achievement and engagement. Authentic work incorporates QFT into its definition by allowing students to take ownership of their own learning, asking questions about real world problems, and promoting student discourse.

Hafen et al. (2012) examined the extent to which high school students' perceptions about academic competence, teacher connection, and autonomy are associated with student-reported and observed engagement across the school year. In this study, 578 diverse students in 34 high school classrooms participated. At the beginning and end of the course, the authors collected data on observed student engagement, student self-reports of engagement, perceived academic abilities, perceived teacher connections, and perceived adolescent autonomy. They used cross-lagged models to see whether there were associations between autonomy, competence, and connection to student engagement. The authors found that allowing and encouraging student autonomy in the first few weeks increased their engagement throughout the course. Using QFT encourages student autonomy. If this protocol is taught during the first 3 weeks of school, it increases engagement throughout the course.

Li and Lerner (2013) wanted to determine how affective, behavioral, and cognitive engagement interact to influence one another. In this study, the authors took data from the longitudinal 4-H Study of Positive Youth Development. The sample consisted of 1,029 students from Grades 9–11. Each of these students completed a student questionnaire for at least two of the three grade levels. The questionnaire required completing 4-point Likert scales for subcategories of behavioral, emotional, and cognitive engagement. The authors tested the directionalities of the relationships between the three types of engagement using latent autoregressive and cross-lagged analysis. The analysis indicated that behavioral and emotional engagement were related bidirectionally, and behavioral engagement influenced cognitive engagement (but not vice versa). Unlike the present study, Li and Lerner looked at the three components of engagement at the school level, not the classroom level. The current study therefore adds to the research with regard to how these three dimensions interact at the classroom level.

M.-T. Wang and Eccles (2012) examined the influence of supportive relationships with teachers, peers, and parents on the trajectories of three dimensions of student engagement: affective, behavioral, and cognitive. The research questions addressed were: What patterns of growth exist in adolescents' perceived school engagement from middle to high School? Do these patterns differ by gender and race or ethnicity? Does social support from teachers, peers, and parents reduce the rate of decline commonly reported in studies of school engagement? This longitudinal study included 1,479 students recruited in seventh grade and followed through 11th grade. The results indicate a decrease in perceived school engagement in terms of school compliance, participation in extracurricular activities, school identification, and subjective valuing of learning. The authors concluded that

> different sources of social support were not equally important in their impact on school engagement, and the effect of these sources differed by the aspect of engagement studied. For instance, peer social support predicted adolescents' school compliance more strongly and school identification less strongly than teacher social support. (M.-T. Wang & Eccles, 2012, p. 877)

The protocol of QFT creates a safe place to ask questions and, when completed faithfully, allows students to build peer-to-peer relationships. These relationships can help them feel more invested in class and increase engagement.

Chase et al. (2014) used the tripartite model of school engagement (behavioral, emotional, and cognitive) to look at the relationship between school engagement and academic success. Like Li and Lerner (2013), the researchers took data from a sample of 710 students from Grades 10–12 who took part in the larger longitudinal 4-H Study of Positive Youth Development. In this study, participants completed the 15-item Behavioral-Emotional-Cognitive School Engagement Scale (five items for each dimension of engagement), and the authors measured academic achievement using self-reported grade point average: “The study sought to determine the magnitude and direction of the relationships among the student’s GPA [grade point average] and behavioral, emotional and cognitive school engagement across 3 years of high school” (Chase et al., 2014, p. 891). The authors used a structural equation model that used factor analysis and multiple regression. The results suggested a bidirectional, reciprocal relationship between school engagement and academic achievement. According to the authors, the strongest predictor of grade point average in Grade 12 was behavioral engagement in Grade 10. Two other findings were that emotional engagement in Grade 10 significantly predicted grade point average in Grade 11, and grade point average in Grade 10 positively predicted cognitive engagement in Grade 11. Unlike the present study of QFT, these results derived from a multidimensional evaluation of school engagement, not classroom engagement.

Harris (2008) conducted a phenomenographic study of teachers' perceptions of the meaning of student engagement. The author found that most existing research was quantitative and wanted to better understand how teachers define engagement by using a qualitative approach. For the study, the author interviewed 20 teachers (35% men and 65% women) from three high schools in Queensland, Australia, using a semistructured interview protocol. After applying bracketing, six themes emerged:

> These categories have been titled: Behaving, Enjoying, Being motivated, Thinking, Seeing purpose, and Owning. While the first category contains primarily behavioral understandings of engagement, the second two, Enjoying and Being motivated, focus more on psychological aspects of engagement. In the final three categories, emphasis is placed on cognitive aspects of student engagement. (Harris, 2008, p. 65)

The themes that emerged supported the concept of engagement as a multidimensional construct. More importantly, the study provided empirical evidence that it is wrong to assume that teachers have a common lens through which they view engagement.

Cooper (2014) conducted a mixed-methods study by analyzing how and why student engagement differs among 1,132 students across 581 classes in one diverse high school. Students completed a survey that asked them to report each of their enrolled classes separately. Students reported six different classes on average (maximum eight) across 106 different teachers. The author completed a factor analysis and then a case study of five different classes. Unlike researchers mentioned above, Cooper examined both how and why certain practices engage students and what types of instruction leads to engagement. With students reporting on multiple classes, the author could look at engagement through students' eyes within and across classes. Correlations revealed that 29% of the variance was at the student level and that 71% of the variance was at the class level. The author uncovered three sets of teaching practices that could play a role in increasing engagement: connective instruction, academic rigor, and lively teaching. Connective instruction is when a teacher helps students establish connections to the teacher as well as the content. Academic rigor is where a class provides learning tasks and environments that require high levels of cognition. Lively teaching is when a teacher delivers instruction in an active fashion, such as by using games, collaborative grouping, and student-driven assignments (Figure 3).

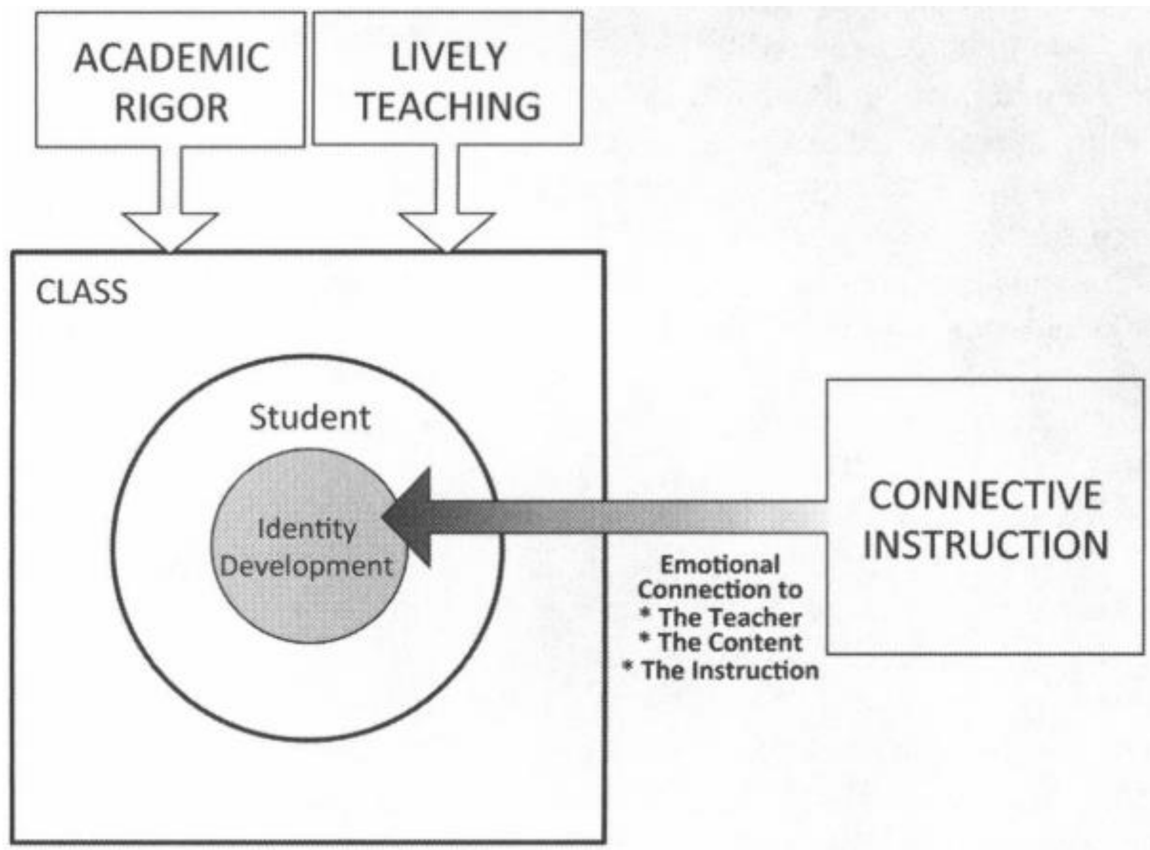


*Figure 3.* Theorized relationships among student identity development and the three types of teaching practices for eliciting engagement. From "Eliciting Engagement in the High School Classroom: A Mixed-Methods Examination of Teaching Practices," by K. S. Cooper, 2014, *American Educational Research Journal*, *51*, p. 367.

Cooper found that connective instruction predicted engagement more than 7 times as strongly as academic rigor or lively teaching:

> Given the importance of engagement to academic success, increasing engagement can no longer rely on teachers' idiosyncratic teaching styles. With a stronger, more systematic understanding of how various teaching practices link to

> engagement, educators can begin to more uniformly modify classes for increased engagement. (Cooper, 2014, p. 397)

Using QFT provides opportunities for students to emotionally connect to the content by asking questions that they are interested in answering.

**Constructivism**

Constructivism is based on Piaget's (2009) theory of cognitive development. This is a theory that explains how people acquire knowledge and learn (Bada, 2015). It has helped drive research focused on student-centered learning. A constructivist learning environment encourages active learning, students taking ownership of their knowledge, grounding knowledge in real-world experiences, and allowing students to transfer knowledge into new situations. Bada (2015) clarified:

> An important restriction of education is that teachers cannot simply transmit knowledge to students, but students need to actively construct knowledge in their own minds. That is, they discover and transform information, check new information against old, and revise rules when they do not longer apply. This constructivist view of learning considers the learner as an active agent in the process of knowledge acquisition. (p. 66)

Table 1 outlines the major differences between a traditional classroom and a constructivist classroom. Some of the important highlights are moving toward a classroom designed to pursue students' interests in which there are opportunities to question and build on what students know and the process of learning is as important as the product.

Other benefits of a constructivist classroom include students learning how to ask their own questions based on what they already know and what they are curious about:

> Constructivism promotes social and communication skills by creating a classroom environment that emphasizes collaboration and exchange of ideas. Students must learn how to articulate their ideas clearly as well as to collaborate on tasks effectively by sharing in group projects. Students must therefore exchange ideas and so must learn to "negotiate" with others and to evaluate their contributions in

> a socially acceptable manner. This is essential to success in the real world, since they will always be exposed to a variety of experiences in which they will have to cooperate and navigate among the ideas of others. (Bada, 2015, p. 68)

If these are goals in constructivist teaching, and educators understand how this helps students learn, explicitly teaching students how to ask their own questions and collaborate with peers is a logical step toward creating independent learners.

Table 1

*Differences Between Traditional Classrooms and Constructivist Classrooms*

| Traditional classroom | Constructivist classroom |
|---|---|
| Curriculum begins with the parts of the whole. Emphasizes basic skills. | Curriculum emphasizes big concepts, beginning with the whole and expanding to include the parts. |
| Strict adherence to fixed curriculum is highly valued. | Pursuit of student questions and interests is valued. |
| Materials are primarily textbooks and workbooks. | Materials include primary sources of material and manipulative materials. |
| Learning is based on repetition. | Learning is interactive, building on what the student already knows. |
| Teachers disseminate information to students; students are recipients of knowledge. | Teachers have a dialogue with students, helping students construct their own knowledge. |
| Teacher’s role is directive, rooted in authority. | Teacher's role is interactive, rooted in negotiation. |
| Assessment is through testing, correct answers. | Assessment includes student works, observations, and points of view, as well as tests. Process is as important as product. |
| Knowledge is seen as inert. | Knowledge is seen as dynamic, ever changing with experiences. |
| Students work primarily alone. | Students work primarily in groups. |

*Note*. From “Constructivism Learning Theory: A Paradigm for Teaching and Learning,” by S. O. Bada, 2015, *Journal of Research and Method in Education, 5*, p. 68.

Savasci and Berlin (2012) conducted a multiple cross-case study to better understand science teachers’ beliefs and practices related to constructivism in the classroom. Their research questions centered around the beliefs teachers had regarding constructivism, how they implemented their beliefs in science classrooms, whether their beliefs were consistent with their classroom practices, and the factors that influenced the implementation of constructivism in the classroom. The authors examined four science teachers from four different school settings in a Midwestern urban school system. Over a period of 4 months, the researchers conducted two semistructured interviews per participant, administered a demographic questionnaire, administered the Constructivist Learning Environment Survey (preferred and perceived forms), made classroom observations, and gathered classroom documents. The five main categories of the Constructivist Learning Environment Survey are personal relevance, scientific uncertainty, critical voice, shared control, and student negotiation.

One of the main findings was that there was a disconnect between science teachers' preferred and perceived beliefs related to constructivist components in the science classroom and observations of their classrooms. The most preferred constructivist components were personal relevance and student negotiation. Personal relevance refers to the students learning about science and applying it to their life outside school. Student negotiation occurs when students engage in scientific discourse with their peers to build their knowledge. The most perceived component was critical voice: the ability to voice opinions on the quality of learning activities and to ask the *why* questions. Shared control was the least preferred, perceived, and observed constructivist component. According to the authors, "In summary, teachers expressed beliefs were not consistent with their classroom practice" (Savasci & Berlin, 2012, p. 76). During the interviews, the most frequently self-reported challenges to implementing a constructivist classroom were student behavior and student ability. These findings can support the creation of professional development to help teachers close the gap between what they believe are strong instructional practices and what happens in their classrooms because of circumstances they cannot necessarily control. The findings can also support development of protocols to help teachers with the behaviors of their students and help teachers learn how to approach learning for students of varying abilities.

Krahenbuhl (2016) explained that educators frequently confuse the learning theory of constructivism and the pedogeological theory of constructivism, which are not the same. Educators discussing constructivism often draw on student-centered approaches, active learning, construction of meaning, discovery, inquiry, and collaboration because they believe these techniques are student centered and increase student engagement. However, without any direct instruction in content, students often end up misguided and form incorrect concepts. Krahenbuhl warned administrators to avoid confusion regarding constructivism as it applies to new teacher evaluation systems. Just because students are not actively walking around the room and doing an activity does not mean they are not learning. Educators need to be aware that “your students are not experts—they need extensive opportunities to develop background knowledge and scaffolds to even remotely engage in these ‘expert’ skills in a way that contributes successfully to their development” (Krahenbuhl, 2016, p. 101). The implication of Krahenbuhl’s article is that educators should use diverse strategies in lesson development. Teachers still need to guide instruction and give students the breadth of expert knowledge they will need to succeed in the world without having to google everything. Educators must teach students how to apply knowledge and give them opportunities to process content and make connections between its parts.

**Student-Centered Learning**

Based on constructivism, Dewey's (2002) learning-by-doing model of teaching has evolved into project-based learning. This method shifts away from the teacher-centered model to the student-centered classroom: "Project-based learning creates opportunities for groups of students to investigate meaningful questions that require them to gather information and think critically" (David, 2008, p. 80). Hugerat (2016) found that students who learned science through project-based learning perceived the classroom learning climate as more enjoyable with greater teacher support than those who did not. The study sample consisted of 458 ninth-grade students from two different Arab middle schools in Israel. Half the students received instruction using student-centered, project-based learning strategies, and the other half received instruction using teacher-centered, non-project-based methods. The teacher-centered instructional style focuses on the transmission of knowledge and assessment of content. The student-centered classroom concentrates on the needs of the students and the process of learning while supporting students emotionally.

The goal of the research was to see whether the different teaching strategies affected students' perceptions of the classroom. The author used a questionnaire that contained 38 statements concerning students' perceptions of the science classroom climate. They conducted a factor analysis using the varimax rotation method. Five themes emerged: Satisfaction, Enjoyment and Teacher Supportiveness, Tension and Difficulty, Student–Student Relationships Competitiveness, and Teacher–Student Relationships. The author used multivariate discriminant analysis to derive weights for the five factors. There was no significant difference between the experimental group and the control group for Student–Student Relationships and Competitiveness. The results imply that compared to the students who learned through the teacher-centered style, students who learned with the project-based strategy were significantly more satisfied, enjoyed class more, perceived the teacher as more supportive, and perceived student–teacher relationships more favorably (Hugerat, 2016).

Lee and Hannafin (2016) reviewed existing literature and proposed practical guidelines for teachers who want to use student-centered learning to enhance student engagement. They began with a review of the contributions of Skinner (1969), Dewey (2002), Piaget (2009), and Vygotsky (2011) in the 20th century and how these applied to student-centered learning. According to Skinner, students learn in the form of stimulus–response-reinforcement systems. Dewey believed students needed to have experiences and opportunities to test and explore hypotheses in order to construct meaning. Piaget's cognitive approach to education affirmed that students interact with their environment in order to construct meaning. Vygotsky argued that learning is a social process and that students need to explore concepts of interest within their zone of proximal development, which means that educational designs for students should be neither too easy nor too difficult, and teachers need to provide scaffolding and guidance to be most effective.

After considering the work of these early theorists, Lee and Hannafin (2016) stated that they wanted to "propose a design framework that encompasses motivational, cognitive, social and affective aspects of learning" (p. 707). The key constructs of engagement for student-centered learning are autonomy, scaffolding, and audience.

Autonomy helps students' own their learning and fosters academic performance and engagement. Scaffolding supports students' independent work by having teachers guide students through the learning process and provide them with enough direction to sustain their learning. Educational experiences grounded in the real world in which students create products for a specific audience enhance student motivation (Lee & Hannafin, 2016). Lee and Hannafin combined these three dimensions to create the own it, learn it, and share it framework (Figure 4), which they designed to enhance engagement in student-centered learning. The elements of QFT fall into this framework because students own their own questions, share their questions with peers, and then figure out how they want to go about learning more.

The Association for Middle Level Education (AMLE) designed a qualitative study that used instructional principles outlined in the position paper to investigate how educators are able to apply these practices in a climate of standardized testing and accountability (Edwards, 2015). Specifically, the author examined the practices and beliefs of teachers who implemented the AMLE instructional principles of active learning and multiple learning approaches. The author tried to uncover why teachers in most middle-grade classrooms regularly use direct instruction when those same teachers widely accept active learning as a preferred method of instruction. The study included teachers from different schools and school systems to help understand a variety of influences on middle-grade classroom teachers, because school systems and states vary with respect to policies and regulations that impact teachers' instructional decisions. The author sampled urban, suburban, and world schools with a variety of demographics and at least two teachers of each of the four core subjects from each school. Participants were diverse in terms of gender, ethnicity, and experience.

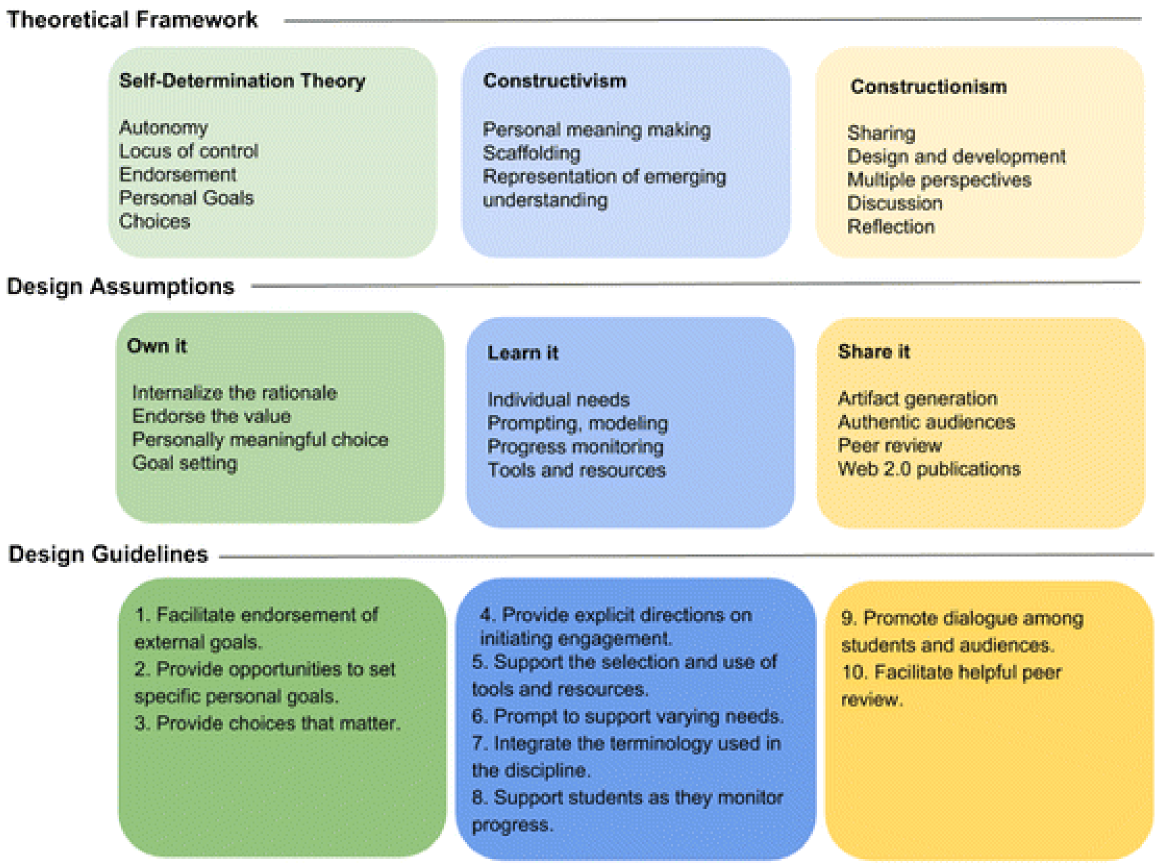


*Figure 4.* The own it, learn it, and share it framework for student-centered learning. From "A Design Framework for Enhancing Engagement in Student-Centered Learning: Own It, Learn It, and Share It," by E. Lee and M. Hannafin, 2016, *Educational Technology Research & Development*, *64*, p. 723.

Certain themes emerged in answer to the first research question regarding the barriers and challenges in implementing active learning and multiple learning approaches. Challenges related to the system included the lack of instructional and planning time caused by testing. Challenges related to students included student behavior, student apathy, and the wide variation in ability as detrimental to the two principles of learning. Challenges related to content included teachers' comfort level with content taught and the difficulty of making content relevant to students' lives. Challenges within the teachers included teachers' internal dilemmas when implementing the principles. Teachers felt like they ran out of ideas or depended on certain strategies too heavily.

The second research question concentrated on how the teachers could implement the instructional principles in a climate of standardized testing and accountability. Three characteristics of teachers were evident: "tenacity, student focused and experimental" (Edwards, 2015, p. 77). During the interviews, teachers revealed that they focused on students when making instructional decisions and were not afraid to try something new. If a strategy did not work, they adjusted their approach instead of giving up.

Creating a student-centered classroom is difficult. Students become used to learning by lecture and are uncomfortable when given autonomy or asked to solve a problem with more than one correct answer. To make the shift from teacher-centered to student-centered methods, teachers need to change their approach. Frank, Lavy, and Elata (2003) explained, "Lecturing to passive students is replaced by encouraging motivation, tutoring, providing resources, and helping learners to construct their own knowledge" (p. 280). In any student-centered approach, guidance by the teacher is critical to success.

**Questioning**

The purposes of questioning—especially questioning as an effective learning tool—have been subject to study for thousands of years. Questioning as an instructional tool can be traced back its use by Socrates, who used questions and answers to challenge assumptions, which could lead to new discoveries and knowledge. Almost 2,000 years after Socrates, Bloom published his taxonomy of the cognitive level of questions. In 1997, Webb released his depth of knowledge study in which he categorized activities in terms of cognitive rigor.

In the past, teachers focused on asking students questions to provoke thinking, but a disconnect has developed between what teachers believe is good questioning and the questions they ask. It has become difficult to teach with the outside pressures of high-stakes testing and competition from social media. Asking good questions is central to learning and sometimes can be more important than getting the answers, particularly when the questions encourage students to think critically. Berger (2014) noted that questioning in America's classrooms has traditionally been the domain of teachers. According to the National Research Council (2012), in *A Framework for K–12 Science Education*, by the end of high school students need to be able to craft questions about the world around them: "Even for individuals who do not become scientists or engineers, the ability to ask well-defined questions is an important component of science literacy, helping to make them critical consumers of scientific knowledge" (p. 54).

Cotton (1988), who conducted a meta-analysis, defined a question in a classroom setting as an instructional cue or stimulus that conveys what students need to do or how they will do it. The author reviewed the relationship between teacher questions and student outcomes. Some of outcomes were building interest and motivation, checking for understanding, reviewing a lesson, developing inquiry, and assessing instructional goals. Science naturally leads to inquiry-based learning, and teaching students how to formulate questions increases their autonomy and engagement.

Although educators perceive questioning as vital to students' learning, what teachers believe about questioning and what occurs in the classroom are different things. Researchers who have investigated asking questions in science classrooms have referred to productive questioning that stimulates student thinking (Chin, 2007; Chin & Osborne, 2008; Ramnarain, 2011). Research related to science classrooms is especially relevant to the new NYSSLS. Examination of how to get students more engaged and invested in learning science through their experiential learning has brought to light the need for students to be able to ask their own questions. As mentioned earlier, autonomy is important for student engagement. Requiring students to ask their own questions fosters autonomy within them.

Chin (2004) wrote about students' learning approaches, problem-based learning, and how scaffolding as soon as students are capable of it can promote more active learning. She reviewed different questioning techniques and provided examples to help teachers. She referred to Bloom's Taxonomy, open and closed questions, productive questions (attention focusing, measuring questions, comparison questions, and action questions), operational questions, nonoperational questions, and questions for creative thinking. Chin (2004) offered six research-based suggestions to stimulate deeper thinking through teacher questioning:

> 1. Familiarize yourself with the levels of thinking elicited by different types of questions.
> 2. Identify the cognitive skills and processes that you would like your students to engage in, and then craft the question to elicit the desired kind of thinking.
> 3. Use wait time.
> 4. Provide a warm and conducive learning environment.
> 5. Pay attention to the wording of your questions and responses.
> 6. Look for questioning opportunities in every lesson. (pp. 19–20)

Chin (2007), as a constructivist, wanted to study how teachers' questions in classroom discourse scaffold student thinking and help students construct scientific knowledge. The study included six 7th-grade teachers of science. The author conducted the study in English in a large class setting, even though the students did not speak

English natively. The author observed 36 lessons across a variety of lesson structures. The goal of the study was to identify different kinds of teacher questioning that can encourage productive thinking. Table 2 displays characteristics of teaching questions in a traditional classroom and a constructivist classroom for easy comparison.

Chin (2007) used audiotapes, video recordings, teacher handouts, samples of student work, and notes from meetings with teachers to quantitatively analyze teacher questioning approaches that stimulate productive thinking. The author provided specific examples of questioning and discourse that foster productive student responses to help science teachers shift to more constructivist practices (Chin, 2007). The four practices outlined were Socratic questioning, verbal jigsaw, semantic tapestry, and framing. Socratic questioning uses a series of questions to prompt and guide student thinking. This practice encourages students to generate ideas, fosters discourse, and encourages students to reflect. Verbal jigsaw focuses on the acquisition of scientific vocabulary; it is helpful for students weak in language skills. Semantic tapestry is used to help students take discrete concepts and tie them together to make a mental model of science phenomena. Framing is an approach in which questions scaffold an idea or topic and structure discussion. This helps students to see the relationships between questions and information.

Table 2

*Traditional and Constructivist Teacher Questioning*

| Category | Traditional | Constructivist |
|---|---|---|
| Purpose of questioning | Evaluate what students know. | Elicit what students think, encourage them to elaborate on their thinking, and help them construct conceptual knowledge. |
| Structure of questioning sequence | Initiation-response-feedback (teacher-student-teacher). | Initiation-response-feedback-response-feedback chain and reflective toss (student-teacher-student). |
| Adjustments to teacher's agenda | Move through a series of questions in accordance with planned agenda. | Adjust questioning to accommodate students' contributions and respond to students' thinking. |
| Nature of questions and responses | Recall, lower order, closed with predetermined short answer. | Open, engage students in taking more responsibility for thinking (higher-order thinking); responses are longer, calling for one- or two-sentence answers. |
| Teacher's responses | Praise correct answers; correct wrong answers; treat students' challenges to her questions as threats. | Delay judgment; accept and acknowledge student contributions in a neutral rather than evaluative manner. |
| Authority for judging answers | Teacher is authority and asserts knowledge claims that she expects students to accept without debate. | Shift authority for evaluating answers from teacher to all students. |

*Note*. From "Teacher questioning in science classrooms: Approaches that stimulate productive thinking," by C. Chin, 2007, *The Journal of Research in Science Teaching*, *44*, p. 819.

Song, Eun, and Glazewski (2017) studied instructor and student experiences with student-generated questions for promoting student interactions. In this case study the authors looked at the perspectives and experiences of a second-language (L2) instructor and students while implementing the use of student-generated questions with a personal response system. Specifically, they wanted to see how student-generated questions encouraged classroom interactions, see how the interactions provided opportunities to practice language, and examine the role of the personal response system in questioning. The sample consisted of two sections of a Korean language (L2) course taught by a single instructor. One section was a second-year Korean II course ($n$ = 15), and the other was a third-year Korean II course ($n$ = 8). Both sections were intermediate, and both had gender imbalances. The average age of students in the second-year course was 19 years, and it was 22 years for the third-year course. The authors used multiple methods of data collection before and after the intervention, including class observations, instructor interviews, student surveys, and student achievement tests.

Although the authors explored four research questions, one is most pertinent here: How are student-generated questioning activities implemented in the L2 classroom to promote classroom interaction? Although the number of interactions did not change much from before the intervention to after, student-generated questions gave students more opportunities to interact orally and actively engage in question creation. These opportunities enhanced students' knowledge of Korean grammar. These findings are important to research on whether teaching students QFT increases student engagement in science class. Using QFT is one way to teach students how to generate and evaluate their own questions and, as in the study of Song et al. (2017), it is important to examine whether QFT can increase student interaction and engagement in the classroom.

**Question Formulation Technique**

Questioning is so important that it is one of the only teaching methods explicitly outlined in Domain 3 of Danielson's (2013) *Framework for Teaching: Evaluation Instrument*. For a teacher to be distinguished,

> the teacher uses a variety or series of questions or prompts to challenge students cognitively, advance high-level thinking and discourse, and promote

> metacognition. Students formulate many questions, initiate topics, challenge one another's thinking, and make unsolicited contributions. Students themselves ensure that all voices are heard in the discussion. (Danielson, 2013, p. 27)

She recognized that student-generated questions are just as important as teacher-generated questions. Teachers often ask students, “Does anyone have any questions?” only for the students to shake their heads no. Is this an indication that students understand everything that happened in class, or do they not know what to ask?

Rothstein and Santana (2011), in *Make Just One Change: Teach Students to Ask Their Own Questions*, described the development of QFT. Often when educators take a deeper look at questions, they turn to Bloom’s taxonomy or Webb’s depth of knowledge as a guide for having teachers ask students higher level questions. Using QFT leads to the opposite approach; QFT is a protocol that a teacher can use to teach students how to formulate their own questions. This technique has six basic components: the teacher presents a question focus, students generate questions following a simple set of rules, students identify different types of questions and learn how to transform them, students prioritize questions, teacher and students discuss the next steps, and students reflect on the process.

During the phase in which student generate questions, they follow a set of rules designed to generate many questions, create a safe space, and allow all voices to be heard. Students have freedom to think divergently and to listen to each other’s questions. While this is happening, the teacher monitors to ensure the rules are followed without judging or answering questions. Before the students prioritize the questions they generated, they have an opportunity to identify the types of questions they are asking and discuss the advantages and disadvantages of open- and closed-ended questions. The convergent thinking begins when the students prioritize their questions based on the teacher's question focus and figure out the next steps. Finally, the students reflect on what they learned from the process. This metacognitive element is vital to help students become more engaged. As the students think about the work they did and what they learned, they need a chance to name discoveries about what they know (cognitive), how they feel (affective), and what they are able to do (behavioral; Rothstein & Santana, 2011, p. 122). This process ties directly to Chin's (2007) description of questioning in the constructivist classroom, outlined in Table 2, especially with regard to the purpose and nature of questioning and the teacher's responses that delay judgement and shift the evaluation of questions back onto the students.

**Conceptual Framework**

Figure 5 illustrates the conceptual framework.

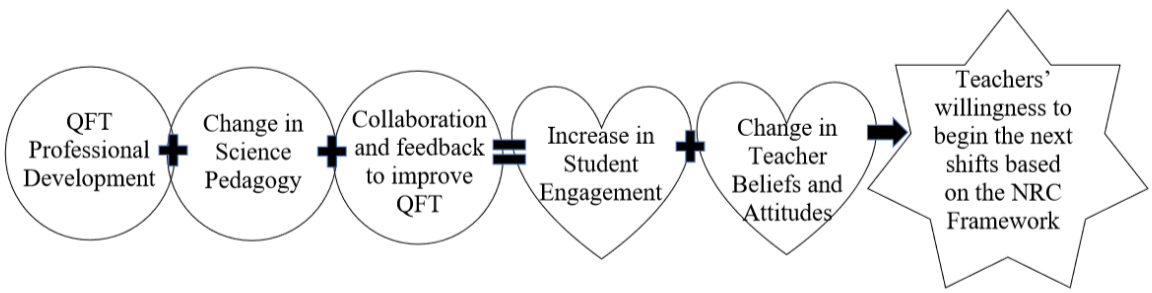


*Figure 5.* Conceptual framework.

Change is always a difficult process. Providing teachers with quality professional development and opportunity for ongoing feedback and reflection will allow them to shift their pedagogy to align to the new NYSSLS. Once they experience student success using new techniques, their beliefs will change, and they will have a more positive outlook on the changes in the standards. This will sustain the four-year transition to the new standards.

**Relationship Between Prior Research and Present Study**

The onset of increased testing and the survival mechanism of teaching to the test has shifted focus away from the constructivist approach. Shifting from the teacher-centered classroom to the student-centered classroom is a pedagogical change. The new science standards have allowed teachers to refocus their energy on creating inquiry-based classrooms. To what extent will implementing the new science standards, shifting to a student-centered classroom, and teaching students how to question phenomena impact student engagement? As the teachers are going through these shifts, what challenges and successes will they face, and what structures are best to support their work?

Researchers have not previously investigated the influence of QFT on classroom-level science engagement. Most researchers investigating QFT have studied social studies classrooms and have not examined its impact on engagement. The purpose of the present study was to analyze whether teaching students to ask their own questions about phenomena increases student engagement. The results of the study can help district and building leaders create professional development plans that support teachers as they learn strategies to increase student engagement. The researcher designed the study to examine both students' classroom engagement levels and teachers' perceptions of what academic, behavioral, and cognitive engagement looks like in their classrooms as they shift their pedagogy. The researcher also discovered roadblocks to engagement, which will inform future studies, and developed suggestions for specific interventions by evaluating the effectiveness of QFT on classroom engagement. Additionally, the researcher examined interventions to increase engagement in terms of how they affect affective, behavioral, and cognitive engagement.

# Chapter 3: Methodology

## Introduction

The researcher's purpose in this chapter is to identify and describe the qualitative and quantitative procedures used to examine the research questions regarding classroom engagement, teacher professional development, and the implementation of new standards. The remainder of the chapter is organized into seven sections that describe the data collection and analysis methods and other procedures used to carry out this study. After presentation of the research questions, the chapter continues with a description of the rationale for the research approach and explanations of the research setting, research sample, data collection and analysis methods, and trustworthiness and the limitations of the study.

## Research Questions

RQ1 asked, Does teaching students how to ask questions through QFT increase total classroom engagement? The independent variable was the time of the test, which was qualitative, had two levels (pretest and posttest), was active, and was within group. The dependent variable was the total score on the CEI, which is quantitative. The inventory uses self-reporting to measure multiple dimensions of engagement: affective engagement, behavioral effortful engagement, behavioral compliance engagement, cognitive engagement, and disengagement. Each of the inventory's 24 statements is rated on a 5-point scale: *each day of class* (1), *weekly* (2), *monthly* (3), *hardly ever* (4), and *never* (5).

RQ2 asked, Is there a difference between affective, behavioral, and cognitive engagement as students become more proficient in QFT? The independent variable was the time of the test, defined as for RQ1. The dependent variables were quantitative and were subscores on the CEI for affective engagement, behavioral effortful engagement, behavioral compliance engagement, cognitive engagement, and disengagement.

RQ3 asked, Do teachers notice a difference in classroom engagement from the beginning to the end of the year after shifting their classroom practices? Do teachers' perceptions of classroom engagement align to the level of students' perceived usefulness of QFT as an engagement tool?

RQ4 asked, Do the teachers feel that the QFT professional development provided to them is valuable based on the five critical levels of professional development evaluation?

**Rationale for Research Approach**

Yin (2003) argued that a system can be studied with one of three types of case study: exploratory, explanatory, and descriptive. Choice of one type over another depends on the purpose of the study. Researchers often use descriptive case studies to present answers to a series of questions based on theoretical constructs (Yin, 2003). The common feature of descriptive study designs is the use of a single sample with no comparison group (Omair, 2015). The researcher chose a descriptive case study design for this study for two main reasons. First, one of the goals of a case study is to develop an understanding of a bounded system. The main purpose of this research was to develop an understanding of how using student-centered questioning affects classroom engagement. Second, descriptive case studies answer questions based on theory. The descriptions of professional development that emerged throughout the research process will help to define the theoretical constraints under which a change in pedagogy is successful.

Yin (2003) pointed out that case study inquiry is only successful when built on the collection and analysis of data from multiple sources. Furthermore, he maintained that "case studies may be based on any mix of quantitative and qualitative evidence" (p. 15). The triangulation of all data relating to a case, both qualitative and quantitative, leads to a credible understanding of the case. The rest of this chapter presents the design of this study, including the sources of data, the methods used to obtain the data, and the analysis of the data.

The researcher analyzed the first two research questions quantitatively and evaluated the last two qualitatively. Creswell (2014) explained that a mixed-method research design is a procedure for collecting and analyzing data by mixing both quantitative and qualitative methods in a single study or a series of studies to understand a research problem. According to Creswell (2012), quantitative and qualitative data together provide a better understanding of a research problem than either type by itself. For this reason, the researcher used a mixed-method, explanatory sequential design. This approach had two phases: First, the quantitative data were collected and analyzed. The results of this analysis then informed the second, qualitative portion of the study. Combining methods in this way minimized the limitations of the study, which provided a stronger understanding of the research problem (Creswell, 2014).

The need for the quantitative portion of the study stemmed from teachers' perceptions of the lack of student engagement in their classrooms. To quantify student engagement and whether an intervention like teaching students how to ask their own questions increases engagement, a pretest and posttest were necessary. After collecting these data, the qualitative interviews established whether teachers' perceptions and students' perceptions matched with respect to classroom engagement. Through the semistructured interview process, the researcher explored the success of the professional development provided to the teachers as they implement new strategies to move toward more student-centered classrooms.

**Research Setting and Context**

This was a case study in which a single school chose to participate. The teachers at this school had expressed concern that students were not engaged in the learning process. At the time of the study, the school was also shifting from Phase 1 of implementing the new NYSSLS standards, building awareness and capacity, to Phase 2, transition and implementation. This research concentrated on the first dimension of the standards: the science and engineering practices, specifically the first practice, asking questions. Focusing on just one piece of the new standards made professional development more manageable for teachers, who were thus more likely to leave the professional development with a desire to try this new method (Guskey, 1985). Tying together existing research on engagement, the power of student-led questions, and shifting teacher practices led to this study. This research could shed light on underlying issues present in the school that act as barriers to engagement. The findings will allow next steps to be determined and implemented to increase student engagement in three dimensions: affective, behavioral, and cognitive. As districts shift to the second phase of implementation, their leaders can use the successes and failures illuminated in this study to better plan professional development.

**Research Sample and Data Sources**

The study took place in a medium-sized high school in a suburban school district on Long Island, New York. The high school consisted of 1,937 students (52.3% male and 47.7% female). With respect to race, 63.5% of students were White, 22.4% were Hispanic or Latino, 7.1% were Black or African American, 6.1% were Asian, Native Hawaiian, or other Pacific Islander, and 0.9% were of another race. Among the total population of students, 26.7% came from poverty, 4.2% were new language learners, and 25.6% had either an individualized education program or a 504 plan.

All science teachers participated in ongoing professional development in QFT, a technique designed to increase student engagement as the teachers shift to the NYSSLS. From among all four Regents science classes at this high school, the researcher selected earth science classes to receive the survey on student classroom engagement. Out of the four Regents science courses, earth science had the lowest passing rate and was the course that could prevent students from graduating. Table 3 details the passing rates of the four Regents courses for 2014–2018. Physics had also had years with low passing rates, but it was not required for graduation and had an extra year for implementation. Therefore, the present study concentrated on earth science.

Table 3

*Five-Year Passing Rates of High School Administered Regents Exams as Percentages*

| | Year | | | | |
|---|---|---|---|---|---|
| Exam | 2018 | 2017 | 2016 | 2015 | 2014 |
| Earth science | 78 | 62 | 77 | 70 | 71 |
| Living environment | 91 | 90 | 94 | 95 | 92 |
| Chemistry | 85 | 75 | 80 | 83 | 78 |
| Physics | 82 | 58 | 71 | 74 | 81 |

The quantitative portion of the study relied on historical data collected by the district at the beginning and end of a school year to quantify whether QFT increased student engagement. All the earth science teachers offered the survey on classroom engagement to their students. Out of these 328 students, 272 responded (53.7% male and 46.3% female): 80.5% were freshmen, 6.7% were sophomores, 10.1% were juniors, and 2.7% were seniors. The 272 students were spread over 14 sections and five teachers. Two of the sections were collaboratively taught special education classes, two were collaboratively taught English as a new language sections, and the remaining 10 were homogeneously grouped.

The researcher conducted qualitative interviews with the earth science teachers to see whether their perceptions correlated with the student data and further examine the professional development associated with implementing strategies of the new standards. These semistructured interviews drew on Guskey's five levels of evaluating professional development. The experience of the teachers ranged from 1 to 15 years. Six of the seven teachers held master's degrees; the seventh teacher was finishing a master's degree within the school year. All teachers in the department taught the course in the same order, and they taught the same units in all classes. Each semester ended with a common unit exam. All participants received a copy of the institutional review board approval of the survey and interview questions. The researcher assured participants of their anonymity and the confidentiality of their personal and demographic information and their school and district.

## Data Collection Methods

In this study, all earth science teachers in a high school administered the CEI to their students during the third week of school. The researcher provided teachers with the CEI in a digital format with instructions on how to have the students complete it to the best of their ability based solely on their engagement in the earth science class. Out of 328 earth science students, 272 completed the survey. The instrument used, the CEI, provides schools with a relatively short but valid instrument that can be used to inexpensively measure classroom engagement (Z. Wang et al., 2014, p. 517). The CEI is suitable for evaluating interventions from late elementary school through high school. For this study, the researcher used the CEI as a pretest prior to students learning the QFT protocol and as a posttest after the intervention had been used over the course of a school year.

Z. Wang et al. (2014) created the CEI at the University of Missouri to fill a perceived gap in research on factors that promote classroom-level engagement. Researchers and their surveys had previously examined only school-level engagement or only one aspect of the three dimensions of engagement: affective, behavioral, and cognitive. The authors developed the study after creating it based on two studies. The first study, conducted with 3,481 students from Grades 4–12, revealed a four-factor model of CEI. Using that model, the authors revised the survey and administered it to the same district 1 year later. Based on the data collected from 3,560 students from Grades 4–12, the final version of the CEI emerged as a five-factor, 24 item survey based on 5-point Likert scales. The researcher received permission to use the CEI for this study from Ze Wang via e-mail on September 17, 2018.

This survey was appropriate for this study because

> the CEI factor structure is invariant across demographic groups and core class subjects is important because it suggests that the CEI could be used with a variety of students and contexts. It can be used for longitudinal research, as well as evaluation of interventions, from late elementary school through high school. (Z. Wang et al., 2014, p. 531)

Furthermore, it was suitable because the instrument had to be capable of measuring at the classroom level, the same level at which the teachers administered the intervention. Because each student completed QFT in a particular class, engagement had to be quantified at the classroom level, not the school level. The CEI was capable of evaluating the effectiveness of QFT, providing feedback to teachers regarding students' perceptions of their classes, and helping teachers improve engagement.

The teachers collected data for this study in a classroom setting at the beginning of the school year. Students took the CEI during the first 20 min of their earth science class period. This 24-item questionnaire uses self-reporting to measure multiple dimensions of engagement: affective engagement, behavioral compliance engagement, behavioral effortful engagement, cognitive engagement, and disengagement. Each of the 24 statements are rated on a 5-point Likert scale: *each day of class* (1), *weekly* (2), *monthly* (3), *hardly ever* (4), and *never* (5). At the end of the school year, the students completed the CEI again in the same class at the same time as the first survey. For both administrations, the classroom teacher asked students to complete the brief survey to the best of their ability and instructed them that the questions applied to their engagement in their current class only. Students submitted their surveys using their student IDs, and the researcher recoded them to protect the students' identities. This instrument and its administration met all guidelines for protecting human subjects.

Because QFT was the intervention, all teachers involved in the study received a general 1-hr hands-on training in the QFT protocol prior to the beginning of the school year. The trainer was an administrator from the district who formed a collegial circle with colleagues to read and discuss the book *Make Just One Change* (Rothstein & Santana, 2011) and attended a 4-hr turnkey training. Within the first 6 weeks of school, all teachers received two subject-specific 40-min follow-up trainings on the use of the protocol, and teachers received opportunities to reflect on the process. At this time, the teachers and trainer troubleshot any concerns they had with the implementation. Throughout the rest of the school year, the trainer held monthly small-group meetings to discuss the ongoing implementation and share successes. The earth science teachers also met in their professional learning communities throughout the school year to discuss this questioning protocol. At the end of the school year, with the intervention complete, the teachers readministered the CEI to all earth science students.

After the student survey, the researcher invited all seven earth science teachers to participate in semistructured qualitative interviews with open-ended questions designed to elicit more information on what drove their beliefs regarding student engagement and professional development. The researcher examined professional development because without an improvement in student performance (academically, behaviorally, or emotionally), taking time away from teachers and spending money on substitutes for professional development programs is pointless. Evaluating these programs requires "a focused, thoughtful and intentional process" (Guskey, 2002, p. 46). The interview questions consisted of Research Questions 3 and 4 along with the questions from Guskey's five critical levels of professional development. Guskey (2016) stated, "The most important part of professional learning planning begins with clear specification of the student learning outcomes to be achieved and the sources of data that best reflect those outcomes” (p. 37).

The five levels are participants’ reactions, participants’ learning, organizational support and change, participants’ use of new knowledge and skills, and student learning outcomes (Guskey, 2000, 2002, 2016). Table 4 illustrates how the researcher developed the questions for the semistructured interviews. Guskey (2016) also noted that there are three implications stemming from this model: Each level is important, tracking at one level does not translate to another, and planning of professional development requires the use of backwards planning that starts with the desired student outcomes.

To triangulate the data, the researcher conducted nonparticipant observations in the earth science classrooms. In addition, the researcher added a single open-ended question at the end of the CEI posttest to collect student insights. Classroom observations verified that the data collected in the quantitative and qualitative portions of the study were visible in the classroom.

## Data Analysis Methods

The researcher screened the data after collecting them. The three items on disengagement were reverse coded. The researcher eliminated any subjects who did not complete both pretest and posttest. Using IBM SPSS (Version 24), the researcher screened data by using descriptive statistics and a histogram to see whether total engagement had a normal distribution. The researcher dealt with any outliers appropriately. Once all posttests were complete, the researcher ran a dependent-sample *t* test for total engagement using the pretest and posttest scores of the students. For the second research question, the researcher repeated the same procedures separately for each of total, affective, cognitive, and behavioral engagement.

Table 4

*Five Critical Levels of Professional Development Evaluation*

| Evaluation level | Questions addressed |
|---|---|
| 1. Participants' reaction | Did they like it?<br>Was their time well spent?<br>Did the material make sense?<br>Will it be useful?<br>Was the leader knowledgeable and helpful?<br>Were the refreshments fresh and tasty?<br>Was the room the right temperature?<br>Were the chairs comfortable? |
| 2. Participants' learning | Did participants acquire the intended knowledge and skills? |
| 3. Organization, support, and change | What was the impact on the organization?<br>Did it affect organizational climate and procedures?<br>Was implementation advocated, facilitated, and supported?<br>Was the support public and overt?<br>Were problems addressed quickly and efficiently?<br>Were sufficient resources made available?<br>Were successes recognized and shared? |
| 4. Participants' use of new knowledge and skills | Did participants effectively apply the new knowledge and skills? |
| 5. Student learning outcomes | What was the impact on students?<br>Did it affect student performance or achievement?<br>Did it influence students' physical or emotional wellbeing?<br>Are students more confident as learners?<br>Is student attendance improving.<br>Are dropouts decreasing? |

*Note*. From "Does it Make a Difference? Evaluating Professional Development," by T. R. Guskey, 2000, *Educational Leadership*, 6, p. 48.

The researcher employed the evaluation coding method to analyze the students' responses to the posttest open-ended question. According to Saldaña (2016), evaluation coding is an effective method that uses "patterned observations or participant responses of attributes and details that assess quality" (p. 141). This approach was appropriate because the researcher wanted to evaluate the benefits of QFT as an engagement tool for students. The researcher coded and analyzed the qualitative data by first reading through the data and pulling out emergent codes before going back and breaking down those codes further in a second pass. Table 5 summarizes the overall data collection methods and their alignment with the research questions.

Table 5

*Data Collection and Analysis Plan Organized by Evaluation Level*

| Data source | Data analysis plan | Research questions |
|---|---|---|
| Level 1 | | |
| Semistructured interview questions 1 and 2 | Evaluation coding to identify themes | 4 |
| Level 2 | | |
| Semistructured interview questions 5 and 6 | Evaluation coding to identify themes | 4 |
| Level 3 | | |
| Semistructured interview questions 4 and 9 | Evaluation coding to identify themes | 4 |
| Level 4 | | |
| Semistructured interview question 3 | Evaluation coding to identify themes | 4 |
| Data from nonparticipant observations. | Evaluation coding to identify themes | 4 |
| Level 5 | | |
| Semistructured interview questions 7 and 8 | Evaluation coding to identify themes | 1, 2, 3 |
| CEI pretest and posttest | SPSS for quantitative statistical analysis | 1, 2, 3 |
| Open-ended question at end of CEI posttest | Evaluation coding to identify themes | 1, 2, 3 |

*Note*. CEI = Classroom Engagement Inventory.

**Issues of Trustworthiness**

Two possible threats to internal validity were selection and history. Differences among the students' learning styles or personalities could have influenced the way they reacted to certain teaching styles. Students are in school for nine periods per day and typically have at least seven different classes. Events in their other classes over the school year could have influenced the way they felt about the examined class. Interaction of testing and intervention can threat external validity. The students received a pretest and posttest. The repeated testing could have increased their awareness of how engaged they were in class or otherwise influenced their behavior. Changes in subject behaviors can also pose a threat to reliability. Over the course of a year, students could have had a myriad of outside experiences that might have changed their outlook in class. For instance, a student could have experienced a family crisis, such as a death or divorce.

**Conclusion**

This chapter outlined the methods and procedures used to conduct this mixed-methods case study. In this case study, the researcher used the CEI to assess the use of QFT as a tool to increase engagement in high school earth science students. The researcher analyzed the data from the CEI quantitatively using IBM SPSS (Version X) for RQ1 and RQ2. Answering RQ3 required quantitative data from the CEI and qualitative data from semistructured interviews of the teachers coded using evaluation coding. The researcher evaluated RQ4 qualitatively using Guskey's (2000) five critical levels of professional development evaluation, outlined in Table 4. The semistructured interview questions derived from these five levels.

# Chapter 4: Results

## Introduction

This chapter contains the analysis of the results as outlined in Chapter 3. The chapter presents the findings broken down and discussed by research question. The 272 earth science students (53.7% male and 46.3% female) were spread over 14 sections and five teachers. The overall sample consisted of 80.5% freshmen, 6.7% sophomores, 10.1% juniors, and 2.7% seniors. Of the five teachers, three participated in the semistructured interviews. All teachers held master's degrees and their experience ranged from nine to 20 years of teaching.

## Results

The researcher used paired-samples *t* tests for RQ1 and RQ2 because students completed a pretest before the intervention and a posttest after. The tests compared the pretest and posttest means within samples. Before running the test, the researcher checked the data for normality and homogeneity of variance. The independent variable was dichotomous, and its levels were paired. The dependent variable was continuous.

RQ1 asked, Does teaching students how to ask questions through QFT affect total classroom engagement? Prior to running the *t* test, the researcher calculated the difference between the pretest total and the posttest total. A box plot revealed 10 outliers. The researcher removed the outliers from the sample because they made up less than 5% of the sample. A histogram produced from the cleaned data revealed a normal distribution.

The paired-sample *t* test indicated a significant difference in total classroom engagement from before the QFT intervention to after (Table 6). Because the *p* value was less than .05, the difference was statistically significant and provided enough evidence to reject the null hypothesis in favor of the alternate hypothesis. The result had an effect size (Cohen's *d*) of .22, which is classified as small. These results show that the total score for student engagement significantly changed from the beginning of the year to the end of the year. The mean decreased, indicating that engagement went down.

Table 6

*Difference in Total Engagement for Students Pre- and Posttest*

| Variable | *M* | *SD* | *t* | *df* | *p* |
|---|---|---|---|---|---|
| Total engagement | −2.47 | 11.44 | −3.18 | 215 | .002 |

RQ2 asked, Is there a difference between affective, behavioral, and cognitive engagement as students become more proficient in QFT? Prior to running the *t* test for each variable, the researcher calculated the difference between the pretest score and the posttest score. Box plots revealed three, 10, eight, two, and one outlier for cognitive engagement, affective engagement, behavioral compliance engagement, behavioral effortful engagement, and disengagement, respectively. The researcher removed the outliers for each variable because they made up less than 5% of the sample. Histograms produced from the cleaned data for the five variables revealed normal distributions in each case.

The paired-sample *t* tests indicated significant differences in the mean scores of cognitive engagement, affective engagement, behavioral compliance engagement, behavioral effortful engagement, and disengagement from before the QFT intervention to after (Table 7). The effect size (Cohen's *d*) was classified as medium for behavioral compliance engagement and as small for the other four variables. Because the *p* value in every case was less than .05, all the differences were statistically significant and provided enough evidence to reject the null hypothesis in favor of the alternate hypothesis. In each case, engagement based on the CEI decreased from the beginning of the year to the end of the year.

Table 7

*Differences in Five Measures of Engagement for Students Pre- and Posttest*

| Engagement variable | *M* | *SD* | *t* | *df* |
|---|---|---|---|---|
| Affective | −1.60 | 4.36 | −5.40 | 215 |
| Behavioral effortful | −1.08 | 3.60 | −4.51 | 223 |
| Behavioral compliance | −0.73 | 1.55 | −7.00 | 217 |
| Cognitive | −1.79 | 0.77 | −4.87 | 222 |
| Disengagement | −1.18 | 3.13 | −5.64 | 224 |

*Note*. For all variables, $p = .000$.

RQ3 asked, Do teachers' perceptions of classroom engagement align to the level of students' perceived usefulness of QFT as an engagement tool? Do teachers notice a difference in classroom engagement from the beginning to the end of the year after shifting their classroom practices? For this research question, the researcher triangulated three kinds of data. First, the researcher examined students' answers to the open-ended question on the CEI posttest: "What do you think about your teacher's use of Question Formulation Technique (QFT) and/or using of I notice/I wonder charts?" Second, the researcher analyzed responses to Question 7 on the interview protocol ("Have you noticed any difference in student engagement in the classroom since you completed your QFT training sessions?") to determine whether teachers' and students' perceptions of the usefulness of QFT aligned. Third, the researcher further examined the specific data from the three teachers used to answer RQ1 and RQ2 and compared it to the responses of their students. Of the five teachers who taught the earth science course, only three were employed in the district at the time of the interviews. All three teachers agreed to participate in the semistructured interviews, and the analysis for each teacher appears below in its own section.

The 263 students who completed the pretest and posttest answered the open-ended question that focused on their perceptions of QFT as an engagement tool. During the first coding pass, four main categories emerged: negative, positive, neutral, or teacher. All but one of the teacher comments was positive about the teacher but gave no feedback on questioning practices. During the second coding pass, the researcher further broke down the positive comments into positive, helpful depending on the lesson, and a reflective of the metacognitive thinking associated with posing questions. For example, "I think it is helpful because it shows me what changed throughout the school year and how my thinking changed."

Out of the 167 positive comments, only 15 fell into the helpful depending category, and three fell into the metacognition category. Table 8 summarizes the coding results for all five teachers along with examples of each code. To better answer the research question, the sections that follow include more detail about the responses of the three teachers and their students.

**Analysis of Teacher 1**

Table 9 summarizes the results of coding for Teacher 1. As an example of this teacher's comments, Teacher 1 said:

> Absolutely. No question about it. And it makes me happy, because otherwise you feel like you're just banging your head against the wall and you're not really getting to students. And there's always going to be . . . Clearly, this is not 100% win-win, but there's always going to the students that are just, no matter what you do, you just can't get to them. But I noticed that there . . . and I wonder if this is

really working. So, I do see more engagement, more involvement, and that makes me happy.

Table 8

*Students' Perceptions of Question Formulation Technique (QFT) as an Engagement Tool*

| Code | *f* | % | Examples |
|---|---|---|---|
| Negative about QFT | 23 | 8.7 | "I believe that the teacher's use of I notice I wonder charts, don't really help me. I generally understand the material better if we just are taught how stuff works instead and then learning how to see it than to not know anything about something seeing it, and not being able to understand what it means."<br>"I think there pointless and it doesn't help me learn."<br>"Unhelpful because we make the chart and then never see it again so what's the point of making one." |
| Positive about QFT | 167 | 63.5 | "The charts help by easing into the topics and make students think about what the question is asking."<br>"QFT and I notice, and I wonder charts are helpful because I get to learn on my own in a way I understand."<br>"I find them useful because it allows us to ask our questions and have them answered by the teacher. It also allows us to think the same question a different person is thinking and allows us to have new questions in mind to ask and asking questions will let us understand the Unit or Topic we are learning or are going to learn soon." |
| Neutral about QFT | 33 | 12.5 | "The QFT is neither helpful nor unhelpful. I get into the lesson either way."<br>"Neither I don't like answering questions."<br>"I don't have a problem with it, and I don't mind it when she uses it." |
| Teacher comments no mention of QFT | 40 | 15.2 | "I like the way she teaches because she fully explains every topic and it helps me."<br>"Teacher 4 is the best teacher ever, he's helpful and I notice that he always is trying to help other students."<br>"My teacher does a great job at teaching the subject and goes through most of the stuff and makes sure we know what we are doing and actually cares about our education." |

Table 9

*Teacher 1's Students' Perceptions of Question Formulation Technique as an Engagement Tool*

| Code | *f* | % |
|---|---|---|
| Negative about QFT | 5 | 10 |
| Positive about QFT | 39 | 78 |
| Neutral about QFT | 2 | 4 |
| Teacher comments no mention of QFT | 4 | 8 |

Paired-sample *t* tests indicated significant differences in the mean scores of total engagement, cognitive engagement, affective engagement, behavioral compliance engagement, behavioral effortful engagement, and disengagement from before the QFT intervention to after for the students of Teacher 1 (Table 10).

Table 10

*Differences in Six Measures of Engagement for Teacher 1's Students Pre- and Posttest*

| Engagement variable | *M* | *SD* | *t* | *p* | Cohen's *d* |
|---|---|---|---|---|---|
| Total | −4.27 | 10.44 | −2.83 | .007 | .41 |
| Affective | −2.81 | 4.46 | −4.37 | .006 | .63 |
| Behavioral effortful | −1.58 | 3.83 | −2.86 | .000 | .41 |
| Behavioral compliance | −0.60 | 1.55 | −2.69 | .010 | .39 |
| Cognitive | −1.10 | 3.72 | −2.06 | .045 | .30 |
| Disengagement | −1.69 | 2.87 | −4.07 | .000 | .59 |

*Note*. For all variables, $df = 47$.

For Teacher 1, 78% of students perceived QFT as a useful engagement tool, and only 10% viewed it negatively. The rest were either neutral or commented about the teacher. This agreed with the teacher's comments about noticing an increase in student engagement. However, the data from RQ1 and RQ2 disagreed. These data showed that student self-reported engagement based on the CEI decreased from the beginning to the end of the year.

**Analysis of Teacher 3**

Table 11 summarizes the results of coding for Teacher 3. As an example of this teacher's comments, Teacher 3 said:

> Absolutely. I've seen more students that are willing to participate, and I've seen more students jotting questions down on tests when they are posed with a new diagram that they didn't see before. They'll create bullet points in their margins to generate those questions to help them answer the question that they were given.

Table 11

*Teacher 3's Students' Perceptions of Question Formulation Technique as an Engagement Tool*

| Code | *f* | % |
|---|---|---|
| Negative | 4 | 6 |
| Positive | 47 | 68 |
| Neutral | 13 | 19 |
| Teacher | 5 | 7 |

Paired-sample *t* tests indicated significant differences in the mean scores of total engagement, cognitive engagement, affective engagement, behavioral compliance engagement, behavioral effortful engagement, and disengagement from before the QFT intervention to after for the students of Teacher 3 (Table 12).

For Teacher 3, 68% of students perceived QFT as a useful engagement tool, and only 6% viewed it negatively. The rest were either neutral or commented about the teacher. This agreed with the teacher's comments about noticing an increase in student engagement. However, the data from RQ1 and RQ2 largely disagreed. These data showed that student self-reported engagement based on the CEI decreased from the beginning to the end of the year for all variables except disengagement.

Table 12

*Differences in Six Measures of Engagement for Teacher 3's Students Pre- and Posttest*

| Engagement variable | *M* | *SD* | *t* | *p* | Cohen's *d* |
|---|---|---|---|---|---|
| Total | −4.96 | 10.75 | −3.20 | .002 | .46 |
| Affective | −2.94 | 4.12 | −4.94 | .001 | .70 |
| Behavioral effortful | −1.46 | 2.84 | −3.55 | .000 | .51 |
| Behavioral compliance | −0.98 | 1.63 | −4.16 | .000 | .60 |
| Cognitive | −1.79 | 5.93 | −2.09 | .042 | .30 |
| Disengagement | 1.02 | 3.12 | −2.27 | .028 | .32 |

*Note*. For all variables, *df* = 47.

**Analysis of Teacher 4**

Table 13 summarizes the results of coding for Teacher 4. As an example of this teacher's comments, Teacher 4 said:

> I have. Like I said, I used certain aspects of that before to engage, but I think that some of the little other techniques like putting it on that white piece of paper and then having the three classes have that up, they can then see that for the next couple of days as we move through because in earth science a lot of things interconnect, that like when we're learning about insulation and then we're learning about the movement of energy, conduction, convection, radiation. That all ties in so when you have all of those questions on there, sometimes when you think of a new question, it might be on there already or a question that we've answered on there might help you to formulate or answer a new question. I found that that's helpful.

Table 13

*Teacher 4's Students' Perceptions of Question Formulation Technique as an Engagement Tool*

| Code | *f* | % |
|---|---|---|
| Negative | 0 | 0 |
| Positive | 32 | 65 |
| Neutral | 2 | 4 |
| Teacher | 15 | 31 |

For Teacher 4, 65% of students perceived QFT as a useful engagement tool, and no students viewed it negatively. The rest were either neutral or commented about the teacher. This agreed with the teacher's comments about noticing an increase in student engagement. In this case, the data from RQ1 and RQ2 agreed. These data showed that student self-reported engagement based on the CEI increased from the beginning to the end of the year for total engagement and two subtypes of engagement (Table 14).

Table 14

*Differences in Six Measures of Engagement for Teacher 4's Students Pre- and Posttest*

| Engagement variable | *M* | *SD* | *t* | *p* | Cohen's *d* |
|---|---|---|---|---|---|
| Total | 4.75 | 9.52 | 3.60 | .001 | .50 |
| Affective | 1.21 | 3.47 | 2.52 | .015 | .34 |
| Behavioral effortful | 1.10 | 2.92 | 2.71 | .009 | .37 |
| Behavioral compliance | −0.06 | 1.02 | −0.41 | .684 | — |
| Cognitive | −0.46 | 5.07 | −0.66 | .514 | — |
| Disengagement | −0.63 | 3.54 | −1.29 | .202 | — |

*Note*. For all variables, *df* = 51. Cohen's *d* not reported for variables without statistically significant differences.

In all cases, the teachers' and students' perceptions of QFT based on their oral or written feedback agreed. All three teachers believed that QFT or having students generate questions increased engagement. All but 5% of students reported positive or neutral feelings about QFT as an engagement tool or reported positive feelings about their teacher. For Teachers 1 and 3, the *t* tests for total engagement, affective engagement, behavioral effortful engagement, behavioral compliance engagement, cognitive engagement, and disengagement showed significant decreases throughout the school year, which disagreed with self-reported qualitative data. Teacher 4 was the only teacher for whom there was a statistically significant increase in total engagement, affective engagement, and behavioral effortful engagement. There was no statistically significant difference for behavioral compliant engagement, cognitive engagement, or disengagement for Teacher 4. Teacher 4 was also the only teacher who had no negative comments, and this teacher had the highest percentage, 31%, of students making positive comments about the teacher in general.

RQ4 asked, Do teachers feel that the QFT professional development provided to them was valuable based on the five critical levels of professional development evaluation?

Answering this question relied on responses to the semistructured interview questions alongside data collected through nonparticipant observations (Table 4). These findings appear below organized in sections according to the five levels adapted from Guskey's (2000) *Evaluating Professional Development*.

**Level 1: Participants' Reactions**

The first level simply examines the participants' initial satisfaction with the professional development experience. The interview questions that addressed this level were "Do you feel that the PD opportunities were worth your time?" and "Do you think the PD activities were well planned and meaningful?" All three teachers found the time spent on professional development valuable. Teacher 1 stated, "The professional development opportunities helped improve my teaching and my craft," and went on to say, "I found that they were absolutely insightful, thoughtful, and beneficial so that I could move forward in my own teaching." Teacher 3 explained, "I thought they had great applications to what we can do in the classroom." Teacher 4 mentioned, "I think that was very helpful because I'm in a group setting, we did it all together and the teachers were from different disciplines." This statement referred to their first day of professional development when they were trained with teachers from other disciplines, not just science, and the teachers found it helpful to share ideas of how to use QFT. Generally, these statements indicated that teachers were satisfied with their learning experience and that the time they spent was worthwhile because it had immediate applications in the classroom.

## Level 2: Participants' Learning

The second level evaluates whether participants acquired the intended learning outcomes from their professional development opportunities. For this study, the training aimed to ensure teachers knew how to train students to generate their own questions when presented with a phenomenon. The interview question that addressed this level was "Describe your efforts at using the techniques you learned in the QFT faculty development training." Teachers 1 and 4 mentioned the use of phenomena as one of their big takeaways, and all three teachers discussed using questioning as an entry point to get students involved in a lesson. Teacher 1 shared, "I used to show phenomenon after I would teach the lesson and doing the phenomenon ahead of time made me suddenly realize, oh, that's so much better." Teacher 4 likewise said, "So how I like to use the QFT techniques in my classroom is to give a short video clip . . . have them look at a certain phenomenon . . . and that's where we start formulating questions on there." Based on this evidence, participants understood the critical attributes of QFT and the use of a phenomenon as a question focus.

**Level 3: Organization, Support, and Change**

The third level depends on the learning organization as a whole and how it supports teachers in their efforts to grow their skills. The interview questions that addressed this level were “Do you think the training was enough to implement the QFT in the classroom?” “Did the school provide you with enough resources to assist you in using the strategies that you learned during the QFT training?” and “Is there anything else that we could provide you with for the QFT or any learning strategies for your classes?” The sentiments of the responses to these questions reflected ample support and training. Teacher 4 discussed the connection between the district-wide training on QFT and professional development provided around the new NYSSLS standards. Teacher 4 further explained that the background in QFT made it easier to incorporate asking questions about phenomena into curriculum writing: “We had QFT as something in our tool belt, we could incorporate it right in.” Teacher 1 specifically descried a positive experience she had had with visiting other teachers’ classrooms as part of the process:

> We were able to go into other classrooms and see how QFT looked in let’s say, an English discipline compared to a science discipline. And I think that’s extremely beneficial to see how other teachers are using it so then that way we can move forward and maybe change how we use it in our own classroom.

The teachers also highlighted the value of the district’s policy of meeting in professional learning communities 15 hours per year after school, where they could direct their own learning. During that time, they debriefed and shared ideas about using QFT in the classroom without having to wait for the next department or district professional development. The evidence led to the conclusion that teachers felt supported in the organization through systems in place that value professional conversations and reflections.

**Level 4: Participants' Use of New Knowledge and Skills**

The fourth level assesses ability to transfer and sustain new knowledge into teaching practices. The interview questions that addressed this level were "How have you used what you learned in the QFT training in your own classroom?" "Has it evolved?" and "If you have not used what you learned in the QFT training sessions to alter your teaching in any way, please explain why." The researcher also used data collected during small-group meetings and nonparticipant observations to support these findings.

During the interviews, all three teachers explained that QFT morphed into showing a phenomenon and having students generate questions. Sometimes they used parts of the QFT protocol, sometimes they created I notice/I wonder charts, and other times they generated questions as a whole class. The teachers spoke about using the techniques in many different parts of their lessons as they became more comfortable using them. Furthermore, each teacher specifically mentioned that this teaching approach gave the content more meaning for students and helped students participate in the lesson.

According to conversations with all five teachers at small-group meetings during the school year of 2018–2019, they all started the year using a full QFT protocol. The researcher observed one of the five teachers during this time, and she carried out all the steps (produce, code, improve, prioritize, prepare next steps, and reflect) during the lesson. All teachers reported diverging from the full protocol or using I notice/ I wonder charts after using the full protocol the first time. The I notice/ I wonder charts came from students looking at a phenomenon, creating a list of what they noticed about the phenomenon, and then taking what they noticed and creating questions. During all of the remaining 14 walkthroughs or full observations completed throughout the year, students asked some form of questions about phenomena. During the 2019–2020 school year, the researcher formally observed the three teachers still in the earth science department, and all three used a version of students generating questions about a phenomenon. These data corroborate what the teachers explained during their interviews. All teachers maintained their new skills and included students generating their own questions in their lesson and unit designs.

**Level 5: Student Learning Outcomes**

According to Guskey (2000), the fifth level answers the question: "How did the professional development activity affect students?" Ultimately this requires looking at multiple measures, including affective, behavioral, and achievement measures. The researcher examined this level in depth in terms of how professional development affected student engagement. The first three research questions addressed part of Level 5. Those research questions did not directly address how learning influenced student achievement. To gain some insight into this area, the researcher asked teachers:

> Do you think the knowledge you gained from the QFT training has increased your students' achievement in any way? If so, how? If not, why do you think this is the case? If yes, what evidence are you basing this on?

Two out of the three teachers interviewed felt that it was too early to determine the impact on student achievement. Teacher 3 explained:

> Absolutely. I feel like my students have been able to tackle more difficult questions and able to tackle more difficult laboratory activities that are based in inquiry because they have the confidence to be okay to ask questions and know that they'll be able to take the information that they are generating and hopefully come back and answer them. So even if they have difficulty with the laboratory activity or with the questions that they were posed with, they have some sort of momentum to continue or to move forward with it.

Evaluating student learning outcomes is the most complex level to draw conclusions from, and it synthesizes the main research in this study. Based on the data collected, students' perceptions of QFT as an engagement tool were positive, but their engagement based on the CEI generally decreased throughout the year. The teachers' perceptions of using questioning as an engagement tool were also positive; however, there was not enough evidence to determine how this tool affected academic achievement.

**Conclusion**

According to the self-reported data from the CEI, students' engagement levels decreased throughout the year. This differed from their perceptions, reported in the open-ended question added at the end of the CEI posttest, in which they reported positive perceptions of QFT as an engagement tool. When the researcher further disaggregated these data by teacher, student engagement for two of the three teachers continued to follow a downward trend, but student engagement increased through the year for one teacher. This case would be interesting case to examine further in future work, which is discussed in Chapter 5.

Overall, the data collected based on Guskey's five critical levels of professional development evaluation indicated that the QFT training was successful. Teachers believed the time they spent during the training was meaningful, they understood the essential features of the QFT protocol, and they felt supported through the systems of the organization. Moreover, teachers applied it to the new NYSSLS science and engineering practice of having students develop questions. Finally, 93% of students reported positive perceptions of QFT as an engagement tool, and teachers reported a perceived increase in student engagement using QFT. However, there was insufficient evidence to assess change in academic achievement.

# Chapter 5: Discussion

> Student engagement in math and science is vital to students' academic achievement and long-term participation in science, technology, engineering and mathematics courses and careers. (Fredricks et al., 2016, p. 5)

## Introduction

This study had three purposes: to examine an intervention to help teachers teach students how to ask their own questions as part of the science and engineering practices outlined in the new NYSSLS, to evaluate the impact of the intervention on students' classroom-level engagement, and to gauge the effectiveness of the professional development created to teach the intervention. This chapter discusses the results from Chapter 4 and their connection to existing research. In addition, the chapter discusses the impact of these conclusions on future professional practice and research.

## Implications of Findings

Based on the student self-reported data from the CEI analyzed for the first two research questions, total engagement, affective engagement, behavioral compliant engagement, behavioral effortful engagement, cognitive engagement, and disengagement decreased throughout the school year. However, the teacher and the student perceptions of QFT as an engagement tool were 93% positive. One possible reason for this discrepancy is the way that students define engagement: They do not necessarily equate producing questions with classroom engagement, and the survey did not mention QFT until the very end. Another possible cause of the decrease in engagement is an implementation dip. Fullan (2006) defined an implementation dip as a dip in performance and confidence as teachers learn new instructional practices and let go of old less efficient ones. For both students and teachers, QFT is new. If teachers do not feel confident employing QFT, they may not develop the technique to its full capacity.

When the researcher disaggregated the data by teacher, the same pattern of decreasing engagement appeared, except among students of Teacher 4. Teacher 4's students reported an increase in total engagement, affective engagement, and behavioral effortful engagement and no significant difference in the other kinds of engagement. A closer look at this teacher's data revealed a lack of negative student comments about QFT as an engagement tool and the greatest percentage of comments, 31%, about how the students felt about the teacher. Students made comments that the teacher was "helpful," "breaks things down," "helps all students," and "explains everything." This implies that the results might be more about the teachers and their relationships with the students than about the use of questioning.

Even though there was a decrease in engagement, the most interesting result for Teachers 1 and 3 was that the largest effect sizes for both teachers were for affective engagement, .63 and .70, respectively, both classified as medium. A possible cause of this is that students felt uncomfortable being taught in an unfamiliar way. Students at high school are used to content-driven teachers who give them direct notes, and students understand that they need to study these notes to do well in the class. This can promote passive learning in students. Using QFT requires active participation, with students sharing their thought processes. Sharing can make students feel vulnerable, which could decrease their affective engagement. Affective engagement relates to interest level and how comfortable students feel in class. The greater a student's interest level, positive affect, positive attitude, positive value held, curiosity, and task absorption are (and the less his or her anxiety, sadness, stress, and boredom are), the greater his or her affective engagement is (Boykin & Noguera, 2011, p. 43). Although the researcher assumed that increased use of student-driven questions would lead to engagement—because students would be driving their instruction—it possibly had a detrimental effect on engagement due to stress and anxiety.

The data collected based on Guskey's (2000) five critical levels of professional development evaluation indicated that the QFT training was effective. The professional development model used for training the participants in the QFT protocol is worth replicating in the future. As discussed in connection with the theoretical framework, administrators need to take the synthesis of Guskey's research and plan systematic opportunities for teachers to receive professional development and apply it in the classroom with sufficient support and time to reflect on the new practices both internally and with other teachers. This aligns with the conceptual framework outlined in Figure 5.

Teachers' perceptions of QFT as an engagement tool were positive. They learned how to implement questioning in the classroom, and this helped them gain confidence. As they gained confidence, they discovered different ways to use questioning, which they perceived as helping students become more engaged. This positive outcome stimulated teachers to continue using student-generated questions into the next school year and had left them open to new professional development opportunities.

**Relationship to Prior Research**

The findings supported the conclusions of Fredricks et al. (2004) regarding student engagement as a multidimensional construct. This was most evident when looking at the effect size broken down according to teacher. The CEI specifies how students feel in a particular class, so breaking the data down by teacher is an important step to take before generalizing to see whether there is consistency amongst the findings.

For Teachers 1 and 3, the largest effect size was for affective engagement. When the researcher combined behavioral effortful engagement and behavioral compliant engagement for all students and then compared affective, behavioral, and cognitive engagement, the differences were small between pretest and posttest, and the effect sizes were also small. Comparing this finding to the results of Li and Lerner (2013) would entrail further research. In this case, the researcher examined classroom engagement, but Lie and Lerner examined school engagement. They also examined the directionality of the relationships between the three types of engagement using latent autoregressive and cross-lagged analysis. Comparison to their results would require further tests to be run on the data.

Teacher 4 was the only teacher for whom both the quantitative and qualitative data supports the findings of Cooper (2014) that that connective instruction predicted engagement more than 7 times more strongly as academic rigor or lively teaching. Connective instruction is when a teacher helps students establish connections to the teacher as well as the content. Among the qualitative data for Teacher 4, there were no negative comments, and 31% of the students commented on how the teacher made them feel supported in class.

During the classroom observations, teachers used questions to help students engage in the content and make connections to the real world by examining phenomena. During the small-group discussions of how the teachers used questioning techniques within the context of their units, they made it clear that they struck a balance between having students generate questions and giving them enough lab experiences or direct content knowledge to answer those questions. This extended Krahenbuhl’s (2016) conclusion that students in a constructivist classroom need to be provided with both experiences to develop knowledge and expert instruction to help guide them.

The key components of student-centered learning to enhance engagement, as outlined by Lee and Hannafin (2016), are autonomy, scaffolding, and audience. In the findings of this study, students demonstrated autonomy when they generated their own questions to guide the direction of their learning, and teachers demonstrated scaffolding with lesson designs that provided students with opportunities to develop knowledge while giving them direct guidance as needed. However, even though student work was grounded in real-world phenomena, students did not necessarily develop products for a specific audience. Future studies should incorporate this aspect of engagement into the professional development.

Many researchers have focused on teachers' use of questioning in the classroom. Chin and Osborne (2008) explored empirical research that student-generated questions are an important yet relatively untapped part of the learning and inquiry process. By the time students get to high school, most of their questions are closed ended, factual, or procedural. Chin and Osborne concluded that explicitly teaching students questioning skills can lead to improved performance in the science classroom. This study extended their research because it looked specifically at how directly teaching students to ask their own questions affects student engagement in earth science classrooms. The students' perceptions of using questioning as an engagement tool were 71% positive, and the teachers realized the benefits of flipping the conventional teacher-centered model.

**Limitations of the Study**

Limitations of the study included the sample size and the length of the study. Ultimately, to get a more robust data set and be able to make better generalizations, this study should be replicated in different content areas, in multiple classrooms, in several school districts. Furthermore, teachers should be given months to refine their skill at using QFT.

Random irrelevancies in the experimental setting could be a threat to the statistical validity of the conclusions. Variations in the environment could have inflated error. Two possible threats to internal validity are selection and history. Differences among the students learning styles or personalities could have influenced the way they reacted to certain teaching styles. Students are in school for nine periods per day and typically have at least seven different classes. Events that occurred in their other classes over the year could have influenced the way they felt about the examined class. Interaction of testing and intervention can threaten external validity. The students completed a pretest and posttest in this study. The repeated testing could have increased their awareness of how engaged they were in class or could have influenced their behaviors. Changes in subject behaviors can also pose a threat to reliability. Over the course of the school year, students could have had a myriad of outside experiences that changed their outlook in class.

The use of data triangulation for the qualitative portion of the study helped address issues of trustworthiness. The semistructured interviews of teachers, the open-ended question answered by students, and the classroom observations all aligned.

Interview participants reviewed the transcripts of their semistructured interviews for accuracy.

**Recommendations for Future Practice**

The impetus of this research was to examine interventions that could help student engagement and begin implementation of the new NYSSLS by, specifically, starting to build teachers' skills using the eight science and engineering practices. Asking questions is only one of the practices. In future, practitioners can use the QFT protocol to help build teacher capacity with respect to teaching students how to ask questions about phenomena. As teachers in school districts start teaching each of the practices, leaders in those districts can research different protocols to help teachers and set up necessary professional development using three principals outlined by Guskey (2002):

1. Recognize that teacher change is a gradual and difficult process for teachers.
2. Ensure that teachers receive regular feedback on student learning progress.
3. Provide continued follow-up, support, and pressure (to initiate change).

Leaders can then apply Guskey's (2000) five critical levels of evaluating professional development to analyze the effectiveness of the professional development. When analyzing Level 5, student learning outcomes, they can use the CEI to gauge student engagement.

**Recommendations for Future Research**

The conclusions of this study can form a foundation for future studies that more deeply examine interventions that increase student engagement at the classroom level. Future work should include more classrooms across multiple school districts. Future researchers should examine the relationship between classroom engagement and academic achievement. The researcher completed this study under the assumption that engagement leads to achievement. Klem and Connell (2004) suggested that focusing first on increasing student engagement, rather than on improving test scores, can foster greater gains in students' academic, social, emotional, and behavioral achievement. Administering the CEI at the beginning and end of a school year and correlating it to high school Regents scores would provide some insight into the relationship between engagement and achievement. There was a discrepancy between the quantitative and qualitative data in this study; adapting the CEI to be more specific about the intervention examined may be an important way to ameliorate this.

Another data source worth examining further is subpopulations of students who may experience student engagement differently, such as students with disabilities, English language learners, and students from poverty. Researchers have shown that students' backgrounds and experiences play a role in their learning profiles. To see how their backgrounds affect engagement would bring further insight to this area of study.

## Conclusion

Teachers need to learn interventions that can increase student engagement and create positive student outcomes (e.g., increased academic achievement, lower dropout rates, and better attendance). The necessary professional development requires critical analysis. Guskey's (2000) five levels are key because they connect how teachers feel to student learning outcomes. Without measuring student learning outcomes, even the best professional development can be a misuse of time and money. If professional development does not directly yield a positive change in student results, teachers will not buy in and there will be no sustained change in pedagogy.

Questioning is critical because it not only plays a role in life but also is part of the new science standards. For students to succeed in school, they need to be engaged in their learning. This study examined whether questioning leads to engagement and whether the professional development necessary to teach teachers how to teach students how to ask questions is effective. It is vital to look at the professional development element, because without changes in teacher practices and reflection on student outcomes, things will not change in the classroom. Through an organizational system, teachers received the opportunity to see QFT across the earth science department, the science department, and across disciplines. This demonstrated the value of question development beyond a single classroom.

The most interesting result was that only Teacher 4's data satisfied the original hypothesis. The researcher expected to find an increase in engagement among students when they were taught how to generate their own questions about phenomena. This paradox can be explained by supposing that students were not used to this approach to learning. In most classes, for most of their educational experience, these students have learned by rote memory or attending to a lecture. Often when observing classrooms using constructivist approaches, students ask, "Why do we have to do this?" or ask, "Can't you just tell us the right answer?" Holding students responsible to do the intellectual heavy lifting makes them uncomfortable—especially those in advanced classes who are afraid to get something wrong. To alleviate this, there needs to be a complete culture shift in K–12 across all disciplines so that students become accustomed to this new way of learning. Teacher 4 embraced QFT and having students generate their own questions based on phenomena. Yet he was the most traditional of all the teachers. This balance might have made students feel more comfortable, which would account for their increased engagement as measured by the quantitative data and open-ended question from the CEI.

**Epilogue**

When the findings for RQ1 and RQ2 did not come out as expected, the process of disaggregating by teacher for RQ3 became very informative. In future research studies, breaking down the data in this way will provide more insight into the case study. Increasing the number of classroom observations and homing in on exactly what students are doing during class would also enrich future studies. A great help for such observations would be the creation or discovery of an observational checklist based on the traits of a constructivist classroom that can be used to assess where the teachers lie on the continuum from traditional to constructivist teaching. These steps would greatly assist future researchers, especially if their results are not as anticipated.

Going through the process of this study validated the researcher's belief in the importance of planning long term professional development that builds on themes each year. When educators begin to look at professional development as an ongoing process rather than a series of one-off events, they become more patient with the process and learn how to reflect upon and refine their teaching skills. As the shift to the new science standards continue, these features will become increasingly important. In the new standards the process is as important as—or more important than—learning of content. Once more, questioning is one out of the eight science and engineering practices that students need to be able to apply when learning science. By the end of this study, the teachers involved were only at the beginning of this process, which must be fully implemented by June 2023.

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# Appendix A

## Institutional Review Board Approval Memo

**IRB-FY2020-323 - Initial: Initial Submission - Expedited - St. John's**

irbstjohns@stjohns.edu <irbstjohns@stjohns.edu>

Mon 12/9/2019 11:27 AM

**To:** annunzia@stjohns.edu <annunzia@stjohns.edu>; Kristen Cummings <kristen.cummings17@my.stjohns.edu>

ST. JOHN'S UNIVERSITY

Federal Wide Assurance: FWA00009066

Dec 9, 2019 11:27 AM EST

Kristen Cummings
Ed Admin & Instruc Leadership

Re: Expedited Review - Initial - **IRB-FY2020-323** *A Mixed Method Case Study of the Effects of Question Formulation Technique on Classroom Engagement in a Secondary Earth Science Classroom and Teachers' Perceptions of this Shift*

Dear Kristen Cummings:

The St John's University Institutional Review Board has rendered the decision below for *A Mixed Method Case Study of the Effects of Question Formulation Technique on Classroom Engagement in a Secondary Earth Science Classroom and Teachers' Perceptions of this Shift*. The approval is effective from December 6, 2019 through December 4, 2020

Decision: Approved

PLEASE NOTE: If you have collected any data prior to this approval date, the data needs to be discarded.

Selected Category: 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Sincerely,

Raymond DiGiuseppe, PhD, ABPP
Chair, Institutional Review Board
Professor of Psychology

Marie Nitopi, Ed.D.
IRB Coordinator

Appendix B

Research Consent Form

**RESEARCH CONSENT FORM**

St. John's University
The School of Education
Division of Administrative and Instructional Leadership

**Introduction and Purpose**

You have been invited to take part in a research study to learn more about how implementing Question Formulation Technique in the Secondary Earth Science Classroom effects classroom engagement and how professional development can be improved to better meet the needs of teachers and students. This study will be conducted by Kristen Cummings as part of her doctoral work at St. John's University in Hauppauge, New York. Her faculty advisor is Dr. Anthony Annunziato in the School of Education, Division of Administrative and Instructional Leadership.

**Procedures**

If you agree to participate in this study, you will be asked to participate in an interview at a time and location of your choice. The interview will involve questions about your experience with Question Formulation Technique and the professional development you were provide. The interview should last approximately 30 minutes. With your permission, your interview will be audiotapes and the researcher may also take notes during the interview. The recording is to accurately record the information you provide and will be used for transcription purposes only. If you choose not to be audiotaped, the researcher will take notes instead. If you agree to being audiotaped but feel uncomfortable at any time during the interview, the researcher can turn off the recorder at your request. Or if you don't wish to continue, you can stop the interview at any time.

The researcher expects to conduct only one interview; however, follow-ups may be needed for added clarification. If so, the researcher will contact you by mail/phone to request this.

## Risks/Discomforts

There are no known risks associated with your participation in this research beyond those of everyday life. The questions that will be asked are strictly about your pedagogy and your perception of Question Formulation Technique in your classroom and your professional development experience. There will be no questions asked about specific students or teachers. You are free to decline to answer any questions you don’t wish to, or to stop the interview at any time. As with all research, there is a chance that confidentiality could be compromised; however, all possible precautions to minimize this risk are being taken.

## Benefits

Although you will receive no direct benefits, this research may help the researcher add to the empirical base of knowledge about using the Question Formulation Technique to increase classroom engagement. It will also help evaluate professional development and uncover ways to make it more beneficial to teachers and students.

## Confidentiality

Your study data will be handled as confidentially as possible. If results of this study are published or presented, individual names and other personally identifiable information will not be used. To minimize the risks to confidentiality, the researcher will not permit anyone access to the data at any time. It will be stored in the researcher’s Google account which is private. Any transfer of data to Microsoft Excel or SPSS software will be done so with all identifiable information removed.

When the research is completed, the researcher may save the tapes and notes for use in future research done by myself or others. The researcher will retain these records for up to 10 years after the study is over. The same measures described above will be taken to protect confidentiality of this study data.

## Rights

***Participation in research is completely voluntary***. You may refuse to participate or withdraw at any time without penalty. For interviews, you have the right to skip or not answer any questions you prefer not to answer.

**Questions**

If there is anything about the study or your participation that is unclear or that you do not understand, if you have questions or wish to report a research-related problem, you may contact Kriste Cummings at 631-258-8677 or email at Kristen.cummings17@stjohns.edu. You can also contact Dr. Anthony Annunziato at 631-218-7709 or email at annunzia@stjohns.edu.

For questions about your rights as a research participant, you may contact the University's Institutional Review Board, St. John's University, Dr. Raymond DiGiuseppe, Chair digiuser@stjohns.edu 718-990-1955 or Marie Nitopi, IRB Coordinator, nitopim@stjohns.edu 718-990-1440.

*********************************************************************************

_____ Yes, I give the researcher permission to quote material from our interview in her dissertation, presentations, or publications, with the understanding that every effort will be made to ensure there is minimal or no identifiable information in the quote.

_____ No, I would prefer not to be quoted.

Please initial

________ I have received a copy of this consent form to keep.

**Agreement to Participate**

______________________________________________

Subject's Name (please print)

______________________________________________ __________________________

Subject's Signature Date

# Appendix C

## Interview Questions

Semi-Structures Interview Questions

Interviewee: Interviewer:

Number of Years Teaching: Number of Years in the District:

Courses Taught:

*Directions: The recorder is recording now. I would like to first say thank you for taking the time to speak with me today about the QFT professional development training and implementation as part of transitioning to the new standards. My first question is…*

1. Do you feel that the PD opportunities were worth your time?

2. Were the PD activities well planned and meaningful?

3. Describe your efforts at using the techniques you learned in the QFT faculty development training.

4. To what extent was the training enough to help implement QFT in the classroom?

5. How have you used what you learned in the QFT training in your own classroom? Has it evolved?

6. If you have not used what you learned in the QFT training sessions to alter your teaching in any way, please explain why.

7. How would you describe student engagement?
    a. Have you noticed any difference in student engagement in the classroom since you completed your QFT training sessions?

8. Do you think the knowledge you gained from the QFT training has increased your students' achievement in any way? If so, how? If not, why do you think this is the case?
    a. If yes, what evidence are you basing this on?

9. Did the school provide enough resources to assist you in using the learning strategies you learned during the QFT training? What else could the school provide to help you use the QFT learning strategies in your classes?

# Appendix D

## Instrument Approval E-mail

RE: Classroom Engagement Inventory

1 message

**Wang, Ze** <WangZe@missouri.edu
Mon, Sep 17, 2018 at 1:22 PM
To: Kristen Cummings kcummings@******schools.org

Hi Kristen,

Yes, you have my permission to use it. Attached is a copy of the CEI.

Good luck with your project!

Ze Wang, Ph.D.
Associate Professor
Statistics, Measurement, and Evaluation in Education
Department of Educational, School and Counseling Psychology University of Missouri

Phone: (573) 882-7602
Email: WangZe@missouri.edu
Webpage: http://faculty.missouri.edu/wangze

**From:** Kristen Cummings <kcummings@*****schools.org>
**Sent:** Monday, September 17, 2018 10:32 AM **To:** Wang, Ze <WangZe@missouri.edu>
**Subject:** Classroom Engagement Inventory

Hi Dr. Wang,

I am a Doctoral student at St. John's University in New York. In my research, I came across your work on measuring student engagement. I am interested in possibly using the Classroom Engagement Inventory to survey high school students. The Farmingdale High School Science Department is working on increasing student engagement through a questioning protocol (Question Formulation Technique). If applicable, we would like to give the survey at the beginning and end of the year to measure engagement. Could you please send me a copy of the survey? If so, would I have permission to use it?

**Kristen Cummings**
Director of Science and Health K-12

Appendix E

Instrument

# Classroom Engagement Inventory

Choose the response that best fits your opinion in THIS class. Some questions will seem the same, but they are asked in a little different way to make sure we really understand your opinion.

* Required

1. **What is your student ID number? (ID should be 9 digits, add zeros on the left if needed.)** *

2. **Course Section Code (This will be provided to you by your teacher.)** *

3. **What grade are you in?** * *Mark only one oval.*

   - 9th grade
   - 10th grade
   - 11th grade
   - 12th grade

4. **How often do you do the following in THIS class that you are in right now?** * *Mark only one oval per row.*

| | 1- Each day of class | 2- Weekly | 3- Monthly | 4- Hardly Ever | 5- Never |
|---|---|---|---|---|---|
| 1- In THIS class, I work with other students and we learn from each other. | | | | | |
| 2- In THIS class, I feel excited. | | | | | |
| 3- In THIS class, I feel interested. | | | | | |
| 4- In THIS class, I form new questions in my mind as I join in class activities. | | | | | |
| 5- In THIS class, I actively participate in class discussions. | | | | | |
| 6- In THIS class, I listen very carefully. | | | | | |
| 7- In THIS class, I go back over things I don't understand. | | | | | |
| 8- In THIS class, I think deeply when I take quizzes in the class. | | | | | |
| 9- In THIS class, I am "zoned out", not really thinking or doing class work. | | | | | |
| 10- In THIS class, I feel happy. | | | | | |
| 11- In THIS class, I pay attention to the things I am supposed to remember. | | | | | |
| 12- In THIS class, I let my mind wander. | | | | | |
| 13- In THIS class, I judge the quality of my ideas or work during class activities. | | | | | |
| 14- In THIS class, I do not want to stop working at the end of class. | | | | | |
| 15- In THIS class, I feel proud. | | | | | |
| 16- In THIS class, I search for information from different places and think about how to put it together. | | | | | |
| 17- In THIS class, I ask myself some questions as I go along to make sure the work makes sense to me. | | | | | |
| 18- In THIS class, I get really involved in class activities. | | | | | |
| 19- In THIS class, I complete my assignments. | | | | | |
| 20- In THIS class, I feel amused (smile, laugh, have fun). | | | | | |
| 21- In THIS class, I just pretend like I'm working. | | | | | |

| | 1- Each day of class | 2- Weekly | 3- Monthly | 4- Hardly Ever | 5- Never |
|---|---|---|---|---|---|
| 22- In THIS class, I try to figure out the hard parts on my own. | | | | | |
| 23- In THIS class, If I make a mistake, I try to figure out where I went wrong. | | | | | |
| 24- In THIS class, If I am not sure about things, I check my book or use other materials like charts. | | | | | |

5. **What do you think about your teacher's use of Question Formulation Technique (QFT) and/or using of I notice/I wonder charts? For example, do you find them helpful/unhelpful/neither/unsure, in getting you engaged in the lesson. Please briefly explain.**

# Vita

| | |
|---|---|
| Name | *Kristen Cummings* |
| Baccalaureate Degree | *Bachelor of Arts, Bucknell University, Lewisburg, Pennsylvania*<br>*Major: Biology* |
| Date Graduated | *May 1997* |
| Other Degrees and Certificates | *Master of Science, Hofstra University, Hempstead, New York*<br>*Major: Education*<br><br>*Professional Certificate in School District, Building Administration, Stony Brook University, Stony Brook, New York (2005)* |
| Date Graduated | *July 1999* |