Teachers’ Transition From Teacher-Centered to Learner-Centered Classrooms Using the Next Generation Science Standards as a Tool

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Submitted in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
under the Executive Committee
of the Graduate School of Arts and Sciences

COLUMBIA UNIVERSITY

2022

Abstract

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This is a study of teachers transition after a professional development (PD). The purpose was to document and characterize the teachers' experiences as they transitioned toward use of the Next Generation Science Standards (NGSS) and more learner-centered teacher practices. The teachers participated in a PD workshop that provided information on the use of the NGSS (NGSS Lead States, 2013). Following the PD workshop, the teachers' experiences as they transitioned in their classroom teaching practices were documented and analyzed. This study used a mixed-methods (qualitative and quantitative evidence) design and emphasized two of the eight science practices: *Asking questions* and *Engaging in argument from evidence*.

To examine the teachers' transition to learner-centeredness, Webb's depth of knowledge chart and learner-centered rubric and the Survey of Science Instructional Practices were used. Four high school science teachers volunteered to participate in this study and were observed, audio-recorded, and interviewed over 9 weeks to document and analyze their transition toward a more learner-centered classroom. Classroom observations started after the teachers participated in a full-day PD workshop. Classroom observations, recordings, and interviews were used to note the frequency with which the participants and their students engaged in the target science practices over the 9 weeks of the study and to identify factors that facilitated or inhibited the teachers' transition toward learner-centered instruction.

The teachers demonstrated a mostly transitional approach over the 9-week observational period. The results showed that during the first through the final classroom observation, the

teachers' practices became more learner centered, but the pattern of progress varied. There was no linear progression from the first through the last observation. The teachers provided a rich and informative narrative about the factors that facilitated or inhibited their transition from a traditional- to a student-centered learning environment. For example, all of the participants stated that the PD was integral in helping them implement the target practices but that they did not receive enough support from colleagues and administrators to fully transition to learner-centered instruction. In addition, the New York State Regents Examinations in June 2019 seemed incompatible with the new science and engineering practices of the NGSS.

This study provides insight into teachers' challenges as they adopt the NGSS and implement the NGSS science and engineering practices in their classrooms. The research is particularly beneficial to teachers who have been textbook-oriented and seek a shift to a learner-centered classroom using the science practices of *Asking questions* and *Engaging in argument from evidence.*

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Acknowledgments

Undoubtedly, the completion of my doctoral dissertation underscores the truism that we all rely on a supporting cast that allows us to stand in the spotlight and execute our plans so that we can achieve our goals. These persons, who have remained invisible for the most part, have in countless, unmentionable, and varied ways contributed to the process and success I have achieved. I consider each supporting role invaluable and worthy of my appreciation. I therefore count it a privilege to hereby acknowledge my supporting cast.

To my sponsor Professor Chris Emdin and Professor Roger Anderson I owe my eternal gratitude for the wisdom, knowledge, guidance, and tireless support you both provided. To my dissertation committee, I will always treasure your insightful feedback that ultimately made my work successful. To my research participants and Dr. Mahfood, I appreciate your involvement and contributions in making my study a reality. To the department chair Professor Mensah and the faculty of the Science Education program, I express my thankfulness.

To my dear friends, “a friend in need, is a friend indeed.” Gifty, Emmanuel, Megan, Fiore, and Jane, you were my rock during this process. A million thanks to you all!

To my family and extended family who prayed for and with me, there is an inadequacy of words to sum up my gratefulness to you. However, for all the times you held my hands and encouraged and supported me, I deeply appreciate each and every one of you, especially my brothers and sisters-Nigel, Steve, Adele, Deleise, Brian, Trevor, Leigh, and Heather. Onica, may God richly bless you!

To my daughters, Avenelle and Althea, I am so happy that you were always there like a ray of sunshine believing in me and encouraging and inspiring me to keep on going. You made

me achieve my goals. To my husband, Greg, your presence and support are immeasurable. All my love and thanks to you.

Finally, this was all possible because of the abiding faith in my God whose goodness and mercy kept and brought me through.

Dedication

I would like to dedicate my dissertation to my daughters, Avenelle and Althea, who were so supportive and patient with me as a parent, and to my husband, Greg, with all my love.

Preface

We are all, directly and indirectly, the products of our environments. Mine has a checkered history. I was trained in the British educational system in Guyana for my formative years in elementary and secondary schools. I migrated to Poland to study biochemistry as a National Scholar. Poland was a socialist country in Eastern Europe. After receiving my Master of Science degree from Wroclaw University in Poland, my initial chemistry teaching was at a prestigious school in New York City. I am now at a public school and have been there for the last 14 years. These collective experiences privileged me to observe and participate in different approaches to education. Irrespective of the differing education systems, it became apparent to me that high school students are reluctant to choose careers in science. The obvious question here is, what contributes to such reluctance among high school students and why?

My quest was to become a better teacher, serve as a motivator and mentor, and encourage more students into science careers. Studying at Columbia University to complete my Doctorate of Education as well as a second MS degree equipped me with the requisite knowledge, tools, strategies, and resources to develop students' learning and implement programs to help students be better prepared for careers in the sciences. This dissertation signals my sincere intention to demonstrate the need for science educators to pivot toward creating learner-centered classrooms as opposed to using traditional teaching strategies and perpetuating student learning that is counterproductive to producing more scientifically literate citizens and sparking students' interest in science careers.

Chapter 1: Introduction

The U.S. education system began focusing on reform in science education in the 1950s after the Russians launched the world's first artificial satellite known as Sputnik (Dow, 1991). The U.S. education system is very complicated and multilayered; thus, there is no simple answer on how to support teachers through the implementation of a new reform effort (Wilson, 2013). As a high school chemistry science teacher, I am deeply passionate about helping my students become scientifically literate citizens and strive to implement the most effective instructional practices for my diverse students. Classroom practices implemented today can help students develop explanatory ideas and better understand their world. This includes preparing them to make decisions about medical policies, nutrition, health, and political policies (National Research Council [NRC], 2012). The most recent science reform in the US involves the Next Generation Science Standards (NGSS), which were adopted in 2013 (NGSS Lead States, 2013). This reform calls for students to engage in new science practices and performance expectations. Specifically, the NGSS envision students engaging in science and engineering practices (SEPs) while using disciplinary core ideas (DCIs) and crosscutting concepts (CCCs) to solve problems and understand how science and scientists work (Krajcik et al., 2014). However, increasing evidence indicates that teachers are unprepared to realize these goals (Clark et al., 2020). My research examined teachers' professional practice after introducing the NGSS and its more learner-centered practices in a professional development (PD) workshop. By definition, learner-centered teaching is an approach that places students (the learners) at the center of learning and classroom organization (Brown, 2003).

Science teachers must accept that the NGSS require a paradigm shift (NRC, 2012). Reiser (2013) argued that the new vision for science teaching and learning presented in the

NGSS requires a deliberate shift from the teaching and learning of science that occurs today in most K-12 science classrooms. Instead of students learning about a scientific theory, this shift requires them to figure out the scientific ideas behind a phenomenon, such as a lesson on the living cell and how and why it functions the way it does (Passmore & Svoboda, 2012). Helping students develop explanatory ideas using a phenomenon while building and refining these ideas over time is a dramatic shift for many science teachers (Windschitl et al., 2008).

To transform classroom practice into meaningful and coherent ways of engaging in constructivism, one must think as a constructivist. According to Windschitl (2002), teachers who have been trained in traditional teacher-centered educational models have difficulty visualizing a constructivist pedagogy. And the teacher-centered approach according to Brown (2003) is mainly being defined as the transmission of knowledge. There may also exist superficial imitations of new practices, such as an overly controlled cooperative learning activity or student projects that do not reflect constructivist approaches. According to Shulman (1987), "Teacher comprehension is even more critical for the inquiry-oriented classroom" (p. 7). Murnane et al. (2012) stated that a teacher's comprehension could influence students' involvement, self-determination, or motivation in their work, which is another pedagogical challenge. However, another critical aspect that should not be ignored is that most teachers are politically pressured to use methods of direct instruction because most teacher ratings are directly related to their student test scores. Most assessments stress basic skills, and, as a result, this encourages teachers to teach to the test itself. As a result, political challenges can arise from reform-oriented teaching, which often generates controversy and substantial conflict, making success difficult to achieve (Windschitl, 2002). The educational methods in teaching science require designs that attract, reward, and promote teachers who can enable effective implementation (Murnane et al., 2012).

As mentioned above, the shift from the traditional teacher-centered method of science education to a learner-centered approach is a difficult transition. Science educators, especially in high schools, are expected to improve science education standards despite this complexity. According to the NGSS, students are encouraged to be active learners, and questioning plays a crucial role in the classroom. But according to a survey of science and mathematics teachers in the US, a small percentage of their PD focused on learner-centered instruction (Banilower et al., 2013); hence, there is a need for effective teacher PD with an emphasis on learner-centered teaching. In the past years, science questioning, or critical scientific discourse, within the classroom has become more of a requirement to improve science practices and scientific literacy (DeBoer, 2000). However, little is known about how science teachers transition from a traditional teacher-centered approach to a learner-centered classroom using the science practices delineated in the NGSS, which require developing students' critical thinking skills (Krajcik et al., 2014). Critical thinking is the process of questioning and challenging existing and long-held assumptions, a skill essential to further development in science. In light of the above, further research is warranted to understand how teachers transition to a student-centered approach as reflected in the NGSS.

The purpose of this research was to document to what extent and how a group of high school science teachers transitioned from a traditional teacher-centered model to a student-centered model after a PD workshop focused on using target elements of the NGSS. The workshop involved helping teachers develop strategies for teaching students how to understand and apply scientific ideas and phenomena and emphasized two of the eight SEPs of the NGSS.

1.1 Rationale for the Study

As I am writing my dissertation, the year 2020 has taken humanity by surprise, and the COVID-19 pandemic has wreaked havoc on how people go about their daily lives. I am encouraged that my study addresses the need for more learner-centered classrooms to encourage students to become better problem-solvers and visionaries who can face and address current and future societal challenges that impact life on our planet. There is a critical need to think outside the box as every aspect of our lives has been changed by the COVID-19 pandemic, which the world has not seen in the past 100 years since the Spanish flu. In addition to challenges in the biological sciences, we are being challenged to venture out into space on expeditions like the Space X program, the first commercialized space flight launched in May 2020.

For our world to progress and adapt to whatever lies ahead, we need to develop ingenious approaches to problem-solving in future generations of students. According to the 2015 Third International Mathematics Science Study , there is a need to fortify our math and science programs. The stakeholders in education and public policy recognize the need for sweeping change in how U.S. students are taught science and have implemented the NGSS to address this need. Not all states have fully adopted (or adapted) the NGSS standards, but New York State (NYS) will fully implement these standards by 2023. This means that NY teachers will be required to make a pivotal shift in their teaching methods to fulfill these new state requirements. The game changers are our teachers, who play a vital role in the education of our students, our future problem-solvers.

The NGSS take a three-dimensional interwoven approach to science and engineering learning: (a) SEPs, (b) DCIs, and (c) CCCs. My research focused on two of the eight SEPs: *Asking questions* and *Engaging in argument from evidence*. Teachers have a tremendous influence in ensuring students possess the foundation needed to be 21st century problem-solvers and visionaries. The learner-centered classroom environment ignites creative thinking and innovative ideas in students, who need to be equipped with these skills to face the challenges that lie ahead.

In this study, I refer to the phenomenological approach to questioning and argumentation, which calls for questions to be anchored in a phenomenon according to the SEPs of the NGSS (Lowell & McNeill, 2019). I am not referring to the phenomenological approach as it is described in the traditional qualitative approach. Also, in this study, my tallies of and emphasis on *Asking questions* and *Engaging in argument from evidence* refer to the extent to which the teachers posed questions and illicited or modeled responses from their students. Argumentation refers to the opportunities created by teachers as a result of their materials, practices, or modeling behavior that illicit argumentation among students.

1.2 Research Questions

1. What are the characteristics of teachers' transition from a traditional teacher-centered to a learner-centered approach following a professional development workshop with a focus on *Asking questions* and *Engaging in argument from evidence* from the phenomenological approach of the NGSS?
2. What characterizes teachers' professional practice during their transition from a traditional teacher-centered to a learner-centered approach with respect to the phenomenological approach of the science and engineering practices of *Asking questions* and *Engaging in argument from evidence?*
3. What factors do teachers identify as facilitating or inhibiting their ability to transition from a traditional teacher-centered to a learner-centered approach with respect to

Asking questions and *Engaging in argument from evidence* from the phenomenological approach of engaging in the science and engineering practices?

1.3 Structure of This Dissertation

In Chapter 1, I began the dissertation by introducing the fact that science reform has been ongoing since the 1950s, when the Russians launched their Sputnik satellite. Today, there is a need for nationwide change in how we prepare students to be scientifically literate citizens. The most recent science reform, the NGSS, was introduced in 2013 and requires teachers to adapt to a more learner-centered classroom. The NGSS have already been adopted or adapted by 44 states, and NYS will begin to fully implement its adopted version of the NGSS in 2023, requiring teachers across the state to shift quickly from their traditional teacher-centered approaches to learner-centered ones.

In Chapter 2, I expound on my description of the NGSS as a tool in my research and explain the two SEPs that were the focus of this study: *Asking questions* and *Engaging in argument from evidence*. By examining how the participants and their students were involved in these two targets SEPs, I observed and measured how the participants transitioned toward more learner-centered classrooms. Then, I describe the following areas of the literature: (a) SEPs of the NGSS, (b) PD for teachers, (c) challenges in implementing the NGSS for teachers, and (d) Webb's (2002) depth of knowledge (DOK) model and levels of questions. A framework of analysis on situated learning and constructivism concludes the chapter.

In Chapter 3, the research design is discussed, which followed a mixed-methods format. Ethical considerations, rigor and reliability, and researcher bias are also addressed. In Chapter 4, the quantitative and qualitative findings for Research Questions 1, 2, and 3 are presented. In Chapter 5, the significant findings are discussed. Lastly, in Chapter 5, I offer my conclusions, discuss the study's limitations, and present the implications of the findings. The chapter concludes with recommendations for further research.

Chapter 2: Literature Review

My research interest is in examining how the SEPs of the NGSS may enable high school teachers to shift their teaching practices to adopt a more learner-centered approach. To explain the rationale for my study, I first review the literature on teacher PD, the SEPs in the NGSS, and the teacher-centeredness to learner-centeredness transition. In my discussion of teacher PD, I address how PD can be used to help teachers understand how to implement the new SEPs. In my discussion of the SEPs, I focus on *Asking questions* and *Engaging in argument from evidence*, which were the two SEPs included in this study. In my discussion of the transition from teacher-centered to learner-centered approaches, I discuss how teachers' beliefs and expectations can affect this shift. This chapter contains two main sections. In the first section, I present the literature relevant to this study. The second section introduces the framework that guided the study design and data analysis.

With the new requirements of the NGSS, NYS teachers face the challenge of repositioning themselves to fully adapt to the new NGSS by 2023 (NYS Education Department, 2019) to increase science achievement. My study was focused on observing the transition of NY teachers using the science practices of the NGSS, specifically of *Asking questions* and *Engaging in argument from evidence*, to create a more learner-centered classroom.

2.1 The NGSS as a Tool for Education Shifts

The NGSS were compiled by a community of science educators, science education stakeholders, scientists, public school educators, and and science education researchers (Achieve Inc., 2022). The foundation of the NGSS is based on *A Framework for K-12 Science Education* (NRC, 2012). The development of the *Framework* was led by the NRC, along with the American Association for the Advancement of Science, the National Science Teachers Association, and

Achieve Inc.. *A Framework for K-12 Science Education* led to the NGSS, whch was led by 26 states and facilitated by Achieve Inc. The goal of the NGSS is to ensure students' college and career readiness in 21st century STEM (NRC, 2012). Today's classrooms should prepare students for informed civic participation, and contemporary sciecen teaching needs to integrate innovative digital tools, rigorous methodologies, and critical thinking skills into the curriculum (Hankey et al., 2017). The NGSS entwine inquiry and content standards instead of teaching science as "discreet fragments of knowledge" (Pruitt, 2014), which often characterized the previous standards (Pruitt, 2014). The NGSS are different from prior standards because they emphasize what students "should know and be able to do" (Kaldaras et al., 2021) following instruction; this is called a performance expectation (PE; NRC, 2013). The NGSS focuses on the PEs of K-12 science education for scientific literacy in the 21st century (NGSS Lead States, 2013). Students should be able to show evidence of the application of their knowledge through the SEPs (Pruitt, 2014).

For successful implementation of the new standards, there need to be changes in classroom practices so they adhere to critical aspects of the NGSS (Reiser, 2013). For example, SEPs are used as verbs (Pruitt, 2014), and there should be a connection between how students learn science and how science and scientists work (Pruitt, 2014). The NGSS stipulate eight SEPs, and the utilization of multiple SEPs is expected in every lesson (NRC, 2013).

The NGSS also focus on equity and diversity by placing high expectations on all students and recognizing that science learning can be supported by relevant cultural practices (Penuel et al., 2015). As a result, the implementation of the NGSS will not be without its challenges. As noted by Emdin (2021), students need to make their own discoveries for "true knowledge is not given, it is discovered" (p. 2), but this requires a shift on the part of teachers who are used to controlling student learning,

For the new NGSS science practices to become a reality, there must be an educational shift directly related to teacher development (Bybee, 2014). Although students will be supported via presentations, simulations, experiments, and textbooks (Reiser, 2013), teachers must be willing to make a major shift in their practices so they are prepared to guide students to investigate phenomena and develop explanatory ideas. Fortunately, there are a healthy number of PDs to support teachers with new materials and content knowledge (CK), such as summer institutes, professional learning school-based communities, and work/study opportunities with practicing scientists (Wilson, 2013).

There is also the need for a shift in assessing learning outcomes, instructional materials, and teaching practices. Many teachers believe they lack sufficient understanding of engineering and are unable to differentiate between engineering design and scientific inquiry (Bybee, 2014). Few students in elementary school have the opportunity to experience authentic science. Few public school teachers engage in argumentation from evidence, develop and use models, and construct explanations scientifically (Penuel et al., 2015). According to Bybee (2014), for the implementation of the NGSS to be effective, the process requires a solid understanding of science and various strategic teaching methods and some of the personal qualities that effective teachers have. Teachers are now faced with the challenge of not having an NGSS-linked lesson checklist of standards-aligned instruction but more of an interdependent approach (Windschitl & Stroupe, 2017). Qualities, such as using appropriate methods, being well informed, recognizing the importance of one's purpose, and having a clear and consistent frame of reference, can affect teacher effectiveness, according to Combs (as cited in Bybee, 2014).

Bybee (2014) emphasizes that the educational shifts in the NGSS are necessary to realize greater teacher development, an improved curriculum, better assessment and accountability, and greater student achievement. The NGSS shifts include the following: from learning facts to explaining natural phenomena, from viewing science as a discipline to viewing it as SEPs, and from treating science learning as unidimensional to treating it as three-dimensional (Bybee, 2014).

For example, there is evidence that student-centered laboratory activities improved both boys' and girls' achievement in physics and biology (Brotman & Moore, 2007). This is another good reason for adopting active collaborative learning into the science curriculum. An equally important point is the role of identity in science learning and students' engagement in science. Brickhouse and colleagues (as cited in Brotman & Moore, 2007) presented an argument for using a situated cognition framework and stated "that for students to learn science, they need to see their own multifaceted identities coinciding with the pursuit of science or as compatible with scientific identities" Science should be made more inclusive to diverse groups of students. Their decisions to go into science also depend on issues surrounding their identity as a people. Learning and educational equity as well as just and fair distribution of learning opportunities and outcomes can be understood only within a specific cultural context (Jordan, 2010).

There are three dimensions that must be addressed to effectively implement a new reform effort: (a) policy management, (b) capability, and (c) culture. According to Blumenfeld et al. (2000),

> Three-dimensional space depicts the key elements that influence the ease or difficulty that reforms may pose to districts in their attempt to adopt and sustain an instructional innovation. (p. 153)

This represents a way of understanding how issues of policy and management, school and district culture, and capabilities interact to influence how a reform unfolds. Standards alone cannot affect big change in education but can serve as the foundation for improvements (NRC, 2012). The proper alignment and implementation of the NGSS will need effective professional development (Reiser, 2013).

2.2 Professional Development

Effective PD can be defined as positive changes in student learning outcomes, in practices, and in teacher knowledge after designed professional instruction (Darling-Hammond et al., 2017). There are various forms of PD. According to Wilson (2013), effective teacher PD requires five general characteristics: focus on content, active teacher learning, teachers' cooperative participation, orientation with other school policies and practices, and sufficient time investment. The shift that is expected of teachers to implement the science practices of the NGSS requires extensive PD for teachers to develop good application strategies. Some of the methods outlined in Penuel et al. (2015) are providing high-quality curriculum materials to both teachers and students, focusing on sustained PD related to the PEs, measuring knowledge-in-use of students' progress, and monitoring teachers' lesson and instruction design. Fortunately, there is a healthy number of PDs to support teachers in using new materials and CK, such as summer institutes, professional learning school-based communities, and work-study opportunities with practicing scientists (Wilson, 2013).

Curriculum implementation in science has been a problem since the 1950s, but other subject areas have minimized the problem by increasing the alignment between their standards, curriculum, assessment, and PDs (Penuel et al., 2009). Poor alignment between curriculum, standards, and assessment can cause teachers to have difficulty in interpreting and acting upon the policymakers' demands. Even if alignment has occurred, Penuel et al. (2009) concluded from case studies that schools should be compelled to provide time for teachers to implement particular programs and curricula. Their findings also suggest that PDs must be tailored to develop more in-depth tools to help improve teachers' comprehension of curricular purposes. In addition, state-sponsored models could provide added resources to best support implementation.

Some of the major challenges with PD for teachers are the lack of coherent goals when there are multiple providers; financial constraints forcing some districts to use the known "one-shot" ineffective PD instead of a repeated, fully expanded PD; and the lack of explicit expectations of teachers when they return to their classrooms (Desimone & Garet, 2015). The variations of PD and their lack of clear goals for how the PD should translate in the participants' classrooms make it difficult to be conclusive about PD studies (Desimone & Garet, 2015). However, one-time PD sessions are often ineffective at supporting changes in teachers' classroom instruction (Moon et al., 2012; Penuel et al., 2009). The science practices of the NGSS are an ongoing nationwide effort and hopefully, there will be iterative conversations that go beyond one-time workshops. Hayes et al. (2016) identified the mechanisms that shape teacher enactment of practices learned in a voluntary PD experience and shed light on how and why the SEP practices are incorporated into teaching. With the adoption of the SEPs in most states, this study may be valuable for complex organizational contexts in conceptualizing teacher change.

The PD for teachers participating in the present study was based on the key features identified for transitioning from traditional teacher-centered to more learner-centered classrooms. According to Desimone and Garet (2015), PD should focus on content, align with school/district goals, meet students' and teachers' needs for knowledge, and involve active learning. The three-dimensional approach to learning espoused by the NGSS uses PEs to measure learning. To mirror the NGSS, PD for science teachers needs an active learning dimension. According to McGee and Nutakki (2017), this dimension incorporates planning, instruction, collaboration, discussion, peer observation, and professional presentations; some of these fundamental elements were included in my study and were considered during the observation of teachers' transition to student-centered science practices.

2.3 Learner Centeredness

For teachers to successfully transition and create a constructivist learning environment (Driver & Oldham, 1986), knowing the elements that align with learner-centered teaching models is key (Gunel, 2008). According to Wohlfarth et al. (2008),

> The learner-centered paradigm departs from traditional teaching models by focusing on students more than teachers and learning more than teaching. (p. 67)

Gunel (2008) noted that a change from traditional teaching in science toward a more learner-centered approach was needed, focusing on the students and redefining the roles of both teachers and students using dialogic interactions. It was concluded that teachers would benefit from more profound understanding of research on the connection between teachers' practices and beliefs and learner-centered environments, especially in diverse settings. Gunel (2008) noted that for teachers to transition to a learner-centered teaching model, it was essential to understand and know the critical factors needed for teachers to successfully implement a constructivist learning environment. According to Moore (2007), teachers commonly face crowded classrooms and underfunding in urban schools. These conditions represent severe issues within today's classrooms and may be credited, among other factors, to the changing demographics and technological influences seen in society.

2.4 Teachers' Beliefs, Practices, and Knowledge

Teachers' beliefs, practices, and knowledge embody the science instructional experience for students (Smith, 1997). Many factors and steps are involved before a concept or theory of teaching practice can be accepted and implemented in the classroom by a teacher responsible for communication of the science to be taught. Moreover, when effective, these practices enhance the discursive identity of students and further develop their scientific literacy.

This is because teachers are the most influential factor in educational change (McComas et al., 1998, p. 23). Eisner (1985) wrote, "In the final analysis, what teachers do in the classroom and what students experience . . . define the educational process" (p. 59).

Understanding the classroom is a cultural challenge and an issue of teacher practice. In this light, researchers have asked what behaviors and attitudes are encouraged or discouraged? What are the relationships between students and teachers? What are the dynamics of the power relationship (Bravmann et al., 2000) Teaching from a cultural perspective is more than addressing content; it is also about bringing students to a shared understanding of what a lesson is and how to participate in it. Teacher qualities, such as using appropriate methods, being well informed, recognizing the importance of one's purpose, and having a clear and consistent frame of reference, can affect teacher effectiveness, according to Combs (as cited in Bybee, 2014).

2.5 Challenges to Teachers' Practices

The research of Windschitl (2002) highlights the challenges that may affect the implementation of a curriculum in the science high school classroom. Windschitl focused on implementing constructivism in practice, and his work emphasizes the challenges associated with this implementation. The four main challenges were conceptual, pedagogical, cultural, and political.

To transform classroom practice into meaningful, coherent ways of constructivism, one must also think as a constructivist (Windschitl, 2002). The conceptual challenges depend on the complexity of the curriculum, which can lead to a disconnect between theory and practice. According to Windschitl (2002), teachers trained in traditional education programs can have difficulty visualizing constructivist pedagogy.

Pedagogical challenges are complex, even for the most experienced teachers. In a study of 24 schools engaged in teaching reforms, most progressive teachers scored considerably below the researchers' highest levels for constructivist pedagogy (Newmann & Associates, 1996). According to Shulman (1987), "Teacher comprehension is even more critical for the inquiry-oriented classroom" (p. 7). Also, supporting student learning requires that teachers understand the developmental process of the learner. However, another pedagogical challenge involves the students' self-determination or motivation in their work. According to Delpit,

> The term political refers to those aspects of education that are linked with the exercise, preservation, or redistribution of power among students, teachers, parents, school board members and other participants in the educational enterprise. (as cited in Windschitl, 2002, p. 154)

Windschitl (2002) stated that political challenges can arise from reform-oriented teaching, which often generates controversy and substantial conflict that can make success difficult to achieve. Most teachers are pressured to use direct instruction methods because most assessments stress basic skills that encourage teachers to teach to the test itself. The standards movement that dominates the education agenda affects constructivist teachers and, ultimately, scientific literacy effectiveness. High-stakes testing that emphasizes memorization and factual learning also influences assessment, curriculum, promotion policies, and other aspects of school life (Windschitl, 2002). Parents, as educational stakeholders, often view constructivist methodologies as experimental and are reluctant to use such pedagogy with their children (Windschitl, 2002).

Holbrook and Rannikmae (2007) stated that science education should be regarded as "education through science" rather than "science through education" (p. 1353). Also, the overarching goal for science teaching is to improve scientific and technological literacy for responsible citizenry; improve the students' ability to evaluate socioscientific issues; and teach students the relationship between science, technology, and society.

The research of Dass et al. (2015) mentioned similar implementation issues to those raised by Windschitl (2002) for the implementation of constructivist reform pedagogies: conceptual, pedagogical, cultural, and political. These studies classified implementation inhibitors as the following: stress during adaptation to new inquiry-based practices (pedagogical/conceptual domain), limited methods for evaluating models (pedagogical domain), classroom/time management issues (political domain), and monetary or material acquisition problems (political/cultural domain).

2.6 Framework for Analysis

To answer Research Question 1, a rubric was used to examine teachers' shift toward learner-centered teaching (Weimer, 2013; see appendix A). The five key areas of classroom practice that were analyzed were the following: (a) role of the teacher, (b) responsibility for learning, (c) balance of power, (d) function of the content, and (e) purpose and process of evaluations. In learner-centered classrooms, the teacher is expected to be a facilitator (Weimer, 2013). Teachers need to understand that in their learner-centered classrooms, their role shifts from knowledge transmitter to knowledge facilitator (Dole et al., 2016). As a result of this shift, more responsibility is placed on students to engage in learning tasks, and the teacher holds students accountable (Weimer, 2013). There also needs to be a shift in the balance of power in the classroom, with students having more control over their learning process (Wiemer, 2013).

Wright (2011) summarizes this shift at the postsecondary level as professors allowing students to have power by choosing their assignments from a given list to develop confidence, become vested in their learning, and become more self-motivated. Within the learner-centered classroom, content functions differently for learner-centered teaching. Weimer (2013) questioned, “How much content is enough” to teach (p. 118) She suggested the answer is not simple since there has always been the talk of “covering” the content (Wiemer, 2013). The fourth fundamental change is the responsibility for learning expected by the student, with the teacher having a supportive role and holding the student accountable (Wiemer, 2013). Roosevelt (2018) spoke of a teacher’s “moral perception” of knowing how and when to enable students to realize their best selves (p.187). Circumstantial and personal factors affecting the motivation and learning of the student should be examined in the framework of learner centeredness (McCombs, 2015). The last practice is the learning potential in assessments (Weimer, 2013), the purpose of evaluation when implementing new standards. As noted by Blumberg (2016), it is a cliché to say, “The purpose of education is to help students learn, complete their degree and succeed after graduation” (p. 194). To help students succeed and transition into their communities is key, and learner-centered practices can promote the best educational practices with this goal in mind.

2.6.1 Learner-Centered Teaching

In this study, I used Widmer’s (2013) definition of learner centeredness which engages students in the messy and hard work of learning, and I examined the participants’ questioning by using Webb’s depth of knowledge (DOK) chart. According to Hess (2010), there are four DOK levels. Level 1 is the recall of information requiring a rote response. Level 2 is more than a single-step process and usually involves classifying or making observations. Level 3 involves strategic thinking and planning using evidence and requires students to explain their thought processes. Level 4 involves planning, complex reasoning, and designing an investigation with several variables (Hess, 2010). In learner-centered teaching, teachers use a constructivist model to help students learn content-related theory, resulting in students positively interacting with others, engaging actively, and constructing knowledge at their own pace (Coupal, 2004). Teachers use constructivist pedagogy to fulfill their essential role as a mentor. According to Becker (2000), teacher leaders with a constructivist philosophy give workshops and classes, mentor other teachers, and participate in professional activities–making a difference to those who are not constructivist.

For teachers to self-reflect on their transition toward using the NGSS science practices, the theories used to develop the Science Instructional Practices Survey (SIPS) for the NGSS by Hayes et al. (2019) are noteworthy. Hayes et al. (2016) define traditional instruction as teacher centered with direct instruction using worksheets or textbook work. In comparison, Hayes et al. (2016) describe NGSS-based instruction as focusing on asking questions based on observations of phenomena, planning experiments, and collecting and analyzing data. These are critical areas for examining the SEPs of the NGSS. Overall, the work by Hayes and colleagues helps explain teacher instructional shifts. Clarke and Hollingsworth (2002) proposed that teacher change is not linear but based on interconnections between external sources of information, professional experimentation, teacher knowledge, teacher beliefs, and student actions and outcomes.

2.6.2 Situative Learning Theory and Instructional Change

According to Aleong and Adams (2020), the NGSS recognizes participation in science activities and the SEPs as inherently involving situative learning. Situative learning is participatory learning and informs the learning environment that teachers create. Lave and Wenger (1991) stated that tasks, functions, activities, and understanding do not exist in isolation.

With the transitioning of teachers to the SEPs, their situated cognition can be an influential factor.

Chapter 3: Methodology

3.1 Research Approach

The NGSS, introduced in 2013, have been adopted or adapted by 44 states and require a major transition from traditional teacher-centered teaching to the learner-centered approach. The NGSS science practices are required to be fully adopted in NYS by 2023. There are specific guidelines as to what NGSS classrooms should look like and how they should operate. As a result, this study used a three-prong approach to better understand how a sample of NY teachers shifted their approach from teacher centered to learner centered using the science practices of the NGSS. The NGSS present eight specific SEPs that are expected to be incorporated in every science classroom. Due to the complexity of the practices, this research emphasized two of the eight SEPs: *Asking questions* and *Engaging in argument from evidence*.

This study began with a PD workshop that I developed and presented to the participating teachers. Following the PD, I observed the participants teaching one of their science classes and rated their practices as well as the performance of their students. I also analyzed the level of the questions the participants asked their students. Finally, I interviewed the teachers about their transition and asked them to complete surveys about the frequency with which they and their students engaged in the target NGSS practices. It is common practice for teachers in NYS to receive 1 day of PD at the beginning of each school year. This day is referred to as superintendent’s day. The teachers are then expected to implement the new methods or techniques presented in the PD with little to no support or follow-up during the school year.

The primary purpose of this mixed-method study was to document and attempt to better understand how teachers in a NY public high school transitioned from a teacher-centered approach to a more learner-centered approach after a 1-day PD workshop, which was of a customary length for teacher PD in NY. The workshop was based on the NYS Science Learning Standards (NYSSLS), which were primarily based on the NGSS to be adopted by NYS. Of the eight SEPs highlighted in the NGSS and NYSSLS, this study narrowed the focus to two practices: *Asking questions* and *Engaging in argument from evidence*. The other SEPs may have been relevant to the participants' lessons and may have been evident during data collection but were not the focus of this study. Through observations, surveys, and interviews, the teachers' and students' frequency of engagement in target behaviors that compose the two target SEPs as well as the factors that teachers identified as facilitating or inhibiting their transition from teacher-centered instruction to learner-centered instruction were examined. The three research questions addressed in this study were presented in Chapter 2.

The remainder of this chapter describes the qualitative and quantitative methods used in this study to investigate how teachers transitioned from a teacher-centered approach to a learner-centered approach. Information is provided regarding the participants and their setting, methods for data collection and data analysis, validity, and reliability.

3.2 Research Design

This study explored high school science teachers' practices when they were encouraged to transition from a teacher-centered to a student-centered approach after a PD workshop based on the NGSS (NGSS Lead States, 2013). The three-dimensional approach to learning outlined in the NGSS and adopted by the NYSSLS was comprised of the following: SEPs, DCIs, and CCCs. These three highlight the great change called for by the new science standards and the substantial shift teachers must make in their teaching practices (Duncan & Cavera, 2015). This study focused on SEPs. While there are eight SEPs articulated in the NGSS and NYSSLS, the focus in this study was on two of them. The NGSS mainly base student learning on PEs, which require the demonstration of science content knowledge integrating all three dimensions.

This study examined three main areas: (a) how teachers adopted the SEPs of *Asking questions* and *Engaging in argument from evidence*, (b) how teachers' and students' engagement in target classroom practices changed over time, and (c) what factors facilitated or inhibited teachers' transition to a more learner-centered approach. This study involved a two-stage analysis that included a within-case analysis and a cross-case analysis (Merriam & Tisdell, 2015). This approach allowed me to look for patterns across the participants and differences between them as they transitioned from teacher- to learner-centered instruction.

3.2.1 Qualitative Research Design

A mixed-method study methodology (Merriam, 2009) was used in this research to observe the planning and deliberate actions of the participants as they made an effort to transition from teacher-centered to learner-centered teaching. The qualitative part of the research study aimed to identify patterns in the participants' shift toward learner-centered teaching. I observed each participant's classroom once a week for 9 weeks. I took field notes, which were keen observations of when questions or argumentation were used; recorded lessons; and transcribed the recordings. Webb's (2002) DOK chart and levels of questioning were also used to measure shifts in teachers' use of the SEPs of *Asking questions* and *Engaging in argument from evidence*.

3.2.2 Quantitative Research Design

A researcher-designed learner-centered rubric was used to describe how the teachers taught in their classrooms. Each 40-minute class period was broken into 5-minute intervals, and I recorded whether a participant engaged in a target practice during each interval (see Appendix B). The SIPS was modified and completed at the midpoint and again after the final week of the 9-week observation period. In addition to this survey, there were semistructured interviews with open-ended questions. These interviews were recorded and transcribed. Participants were also asked to complete a demographic questionnaire.

3.2.3 Setting and Participants

The participants were recruited from a high school in NYS and were willing to learn how to shift their science teaching practices in their classrooms. These participants were chosen because of their willingness to work with the NGSS as a tool to improve their learner-centered approach. The participants were teachers who, initially, all had a disposition for teaching following the traditional science teaching method–relying on discreet packets of knowledge and experimental labs guided by the teacher. As a result of having insight into how these teachers taught, they were considered a good fit for this study. Their participation was voluntary, and the Teachers College Institutional Review Board guidelines for research with human subjects were followed with IRB code 19-200. All four participants agreed to volunteer their time for the 9-week research study period. After the participants completed the IRB consent and acknowledgement form, the study began. There was no extrinsic reward for participating. However, it was hoped that this research would enhance the participants' teaching skills and improve their understanding of what would be expected in the upcoming 2023 implementation of the NYSSLS. The study began with the 1-day PD workshop, which took place on a Saturday from 9 a.m. to 5 p.m. At the workshop, participants were presented with the phenomenological approach of the NGSS, focusing on the three-dimensional approach of science learning. The workshop emphasized two of the eight science practices: *Asking questions* and *Engaging in* *argument from evidence*. During the workshop, the teachers designed a complete unit lesson. They were presented with the critical characteristics of having an NGSS-based learner-centered lesson with driving questions and PEs.

The PD workshop initiated the 9 weeks of the observation period in this study. Teachers were asked to use their new knowledge from the workshop to implement a more learner-centered approach in their teaching as they participated in the full 9-week study. The study was conducted at a high school in NYS with four science teachers (Table 3.1)

Table 1: Participants' Demographic Characteristics.

Teacher	Gender	Race/ethnicity	Years teaching	Subject area and type of classroom
Kate	F	African descent	14 (tenured)	Living environment and ELL
Carol	F	Hispanic	10 (tenured)	Bilingual and ENL living environment
Gwen	F	White	7 (not tenured)	General Earth science class with inclusion students (having 504/IEPs)
Ellen	F	White	4 (not tenured)	ENL Earth science class

Two teachers were from the living environment discipline and the other two were from Earth science. One science class was selected for each of the participants and that class was observed once a week for 9 weeks. Of the four science teachers, two were tenured at the time of the study and two were not. They were all female teachers, and their teaching experiences ranged from 4 to 14 years.

3.2.4 PD Workshop

The workshop started with an overview of the NGSS and NYSSLS. Each teacher then designed a lesson unit for her respective subject area (i.e., Earth science or living environment). The lessons were designed using a phenomenological approach and focused on the SEPs of

Asking questions and *Engaging in argument from evidence*. The teachers worked individually and collaboratively to build their first unit lesson at the workshop. The teachers used the tables shown in Appendix C as a guide to *Asking questions* and *Engaging in agument from evidence* as incorporated into the NGSS science standards. Appendix D was used to guide their questioning.

3.3 Data Collection and Analysis

Week 1 of the observation period started on the Monday following the Saturday PD workshop. The same science class of each participant was observed for 9 weeks and was audio recorded each week. Each science class was 40 minutes (see Appendix B). For all 9 weeks of classroom observation, I focused mainly on the teachers' use of the SEPs of *Asking questions* and *Engaging in argument from evidence*. Data were collected from multiple sources. First, I used a checklist to identify how often a teacher asked questions or engaged the students in argumentation during the 40-minute class period. A similar checklist was used to identify when the students engaged in class discussion or argument from evidence. After each class, the completed checklist was compared to the audio recording to ensure accuracy. Second, a modified version of the Learner-Centered Rubric for Classroom Observations (Weimer, 2013) was completed during each classroom observation. The rubric was adapted to better capture the consistency in each teacher's implementation of the target SEPs during each 40-minute class period. Third, Webb's (2002) DOK chart was used to analyze the level of questions asked by the teachers since higher level questions promote greater student-centered learning. This analysis was done using the audio transcripts of the observed lessons. The teachers wore an audio recording pen (an Olympus digital voice recorder VP-10). The built-in USB connector made it possible to upload the files for transcription with the REV.com transcription service. This provided the accuracy and reliability needed for data analysis of the lessons observed. Finally, the teachers were individually interviewed after 4 weeks (midpoint of the observation period) and 9 weeks (end of the observation period) using an in-depth semistructured format. The interviews were conducted in person and lasted an average of 60 minutes each.

3.4 Methods of Data Collection

This study used a mixed-methods design that included qualitative case studies, surveys, and rubrics for quantitative analysis. A mixed-method can enhance the understanding of the research question (Creswell & Clark, 2011). Data sources in the study included observations, rubrics, surveys, lesson plans, and interviews. The study was conducted systematically with four participants: two living environment and two Earth science high school teachers. There was an initial meeting with the researcher, PD presenter, and teacher participants to discuss the research requirements. The researcher explained the required commitment, clarifying all questions the participants had before starting the research and signing the consent forms. This study required a 9-week commitment from the participants. The teachers then had a 1-day PD workshop, from 9 a.m. to 5:00 p.m. on a Saturday so as not to interrupt their regular school-day schedule. The PD was based on the NGSS standards, emphasizing two of the SEPs: *Asking questions* and *Engaging in argument from evidence*. As such, the PD focused on developing a phenomenological-based lesson plan. I then captured the participants' implementation of the target NGSS elements over 9 weeks, from mid-March to May.

3.4.1 Classroom Observation Notes

All four teachers were individually observed once a week for 9 weeks. Each observation lasted for a 40-minute class period. Each observed class was audio recorded, and the lesson plan for the observed class was collected. In addition to the recordings taken of each observed lesson, I took field notes of the observed lessons, mainly focusing on *Asking questions* and *Engaging in* *argument from evidence*, and recorded if teachers engaged in the target teaching practices for each 5-minute interval (see Appendix B).

3.4.2 Teacher Rubrics, Surveys, and Interviews

During each classroom observation, I completed the teacher-centered to learner-centered transition rubrics (see Appendix A) as evidence for a shift in their approach from teacher- to student-centered learning. These rubrics were filled out in class and were cross-checked by re-listening to the audio recordings of the observed classes for accuracy. Each of the four participants also completed a midpoint survey after 4weeks and a final survey at the end of the 9-week observation period (see Appendix E).

The interviews for each participant were conducted after Week 4 and Week 9, following their midpoint and final surveys, respectively. The interviews were each about 60 minutes long and followed a semistructured formt. Each interview was audio recorded and transcribed. The interview questionnaire (Appendix F) served as the basis for the conversation, but the questions were not asked in a rigid order and instead followed each participant's responses. These interviews were focused mainly on summarizing the science practices in the participants' classrooms, their student-centered interactions, their students' classroom responses, and the factors that facilitated or inhibited the participants' transition from teacher- to learner-centered instruction.

3.5 Data Preparation

I used rubrics (during each observation), surveys (at the midpoint and final week), interviews (before, during, and after the observation period), a background questionnaire, transcribed classes, lesson plans, and artifacts of students' work. These data enabled me to develop an in-depth case study of how teachers transitioned from a traditional teacher-centered approach to a more progressive student-centered approach using the NGSS as a tool. The surveys used a 5-point Likert-type scale for each of the two disciplines (living environment and Earth sciences). The interviews helped form more reliable data and with the Likert surveys, transcribed observations, and rubrics allowed for triangulation of the data (Creswell, 2014), allowing me to compare and cross-check the data collected. I also used coding schemes with specific criteria for each code category.

First, to analyze the extent to which the approach from the PD workshop was implemented in the participants' classrooms, I analyzed the classroom rubrics, surveys, questionnaires, and interviews. Coding of the verbatim transcripts of the audio recordings from the teacher interviews and classroom observations was used to document teacher performance. Second, to characterize the transition of Earth science and living environment teachers from a traditional teacher-centered approach to a more learner-centered approach, I relied on the classroom observation rubrics, Webb's DOK chart, and Webb's levels of questioning codes. Finally, to analyze the factors that teachers stated facilitated or inhibited their ability to transition to more learner-centered teaching, two surveys were administered (at the midpoint and end of the observation period) and interviews were conducted at the same points in the study.

3.6 Data Analysis

In this section, I provide a detailed description of the analysis process that I used to examine my research questions. After the collection of the data, both quantitative and qualitative analyses were performed. Rich data were produced from the rubrics, audio recordings of the observed lessons, field notes, frequency charts, surveys, and midpoint and final interviews.

For Research Question 1, the tallies for all the classroom observations over the 9 weeks were summed up and entered into an Excel spreadsheet. These data are presented in Chapter 4. It is important to note that the tallies given during the classroom observations were cross-checked against the audio recordings for each observed class for accuracy. The Excel spreadsheets highlighted emerging patterns.

The average frequency count showed the transitional patterns for the teacher participants. The results are presented in table form in Chapter 4. From the Excel results, it was clear that the participants engaged in the target practices to different extents. Ellen was first (most transitional teacher), followed by Gwen, Carol, and Kate (least transitional teacher). Subsequently, the individual teacher's 9-week observations were tallied in the Excel program and analyzed individually. From this analysis, the highest teacher-centered and student-centered lessons emerged from the rubrics, and Lesson 1 was used as a reference point because it was the first lesson after the PD. It is important to note that Lesson 2 was not chosen regardless of whether it had the highest value because it immediately followed the reference point lesson. After the individual teacher data were compiled, a statistical analysis of the classroom practices categories was done and used to perform a chi-square analysis. The chi-square test of the total frequency was tabulated. This completed the data analysis for Research Question 1.

The frequency levels for *Asking questions* and *Engaging in argument from evidence* for each 5-minute interval and the levels of questions asked based on Webb's DOK chart served as the data to answer Research Question 2. Questions asked in the classroom were coded from the audio transcribed lessons over the 9 weeks of observations. The teachers' questions during their observed lessons were coded from the transcripts using the categories of Level 1 to Level 4. A summation table of the total frequency of the different levels of questions for each teacher was created and analyzed for other patterns or trends toward a more learner-centered classroom. For Research Question 3, the teachers completed the SIPS survey describing the frequency with which they and their students engaged in the target science practices. These surveys were conducted after the fourth and ninth week along with the semistructured interviews. I then further analyzed the interviews for facilitating or inhibiting factors that may have accounted for the teachers' experiences with transitioning toward a more learner-centered classroom. The interviews provided a more in-depth examination of the teachers' practices during the 9-week study. This research process helped triangulate the findings, test for validity and reliability of the study, and confirm the appropriateness of the analysis.

3.7 Validity and Reliability

It is important to clarify specific ethical concerns and challenges with regard to the researcher and the research before discussing the validity and rigor of the data and their analysis.

3.7.1 Potential Ethical Concerns and Challenges

This study involved both quantitative and qualitative data and interpretation of multiple data sets. Although some researcher bias can be reduced through standardization of language in questionnaires, there are still the following potential concerns for the present study: (a) sampling biases, (b) availability and reliability of the data, and the researcher's relationship with the participants

With respect to sampling, the small group of four participants from the same school may have introduced some bias into the study. However, the participants' varied experiences and years of teaching made them valuable contributors to this emerging field of study.

The use of both quantitative and qualitative methods helped triangulate the findings to provide validity of the findings (Creswell, 2014) and clarity for the analysis. As the teachers recalled their experiences, there could have been more emphasis on other aspects; however, I believed it was important to focus on what the teachers said was important to them. My findings and analysis were discussed with my participants to ensure that their classroom practices were checked accurately via the learner-centered rubric and that the levels of their questions were coded correctly.

As a researcher, I endeavored to accurately implement the study and validly perform the analyses. However, I bring my own abilities, skills, and knowledge to interpret and analyze my data. My science teaching experiences in the classroom and as a Science Olympiad coach, science fair project mentor, and after-school lab make-up instructor may have influenced the data collection and analysis processes. I also worked at the same school as the participants.

3.7.2 Elements of Rigor

There were field notes, collectively recorded data, and midpoint and final surveys to demonstrate any vital results from the 9 weeks of observations. I looked for similarities/patterns within the participants' artifacts to check for reliability. I also used member checking as a form of rigor that allowed my participants to review the findings for accuracy and credibility (Creswell, 2014).

3.7.3 Ethics and Reflexivity

This was a qualitative and quantitative study done with a group of teachers whose privacy was protected by referring to them with pseudonyms. There was no form of payment to my research participants, and they all willingly volunteered their time to participate in the study.

4.0 Expected Contributions of the Research

Not many students from elementary to high school have the opportunity to experience authentic science. The goal of the NGSS is to change that so all students engage in science like scientists and engineers do in their real work. This not only makes science learning more accessible and relevant for all students but better prepares students to understand and address the science-based challenges that they will likely face. With NYS requiring science teachers to meet the NGSS-based NYSSLS next year, it is imperative that science teachers develop the understanding, skills, and resources needed to effectively implement these new practices and standards. The shift to the NYSSLS requires a significant transition on the part of teachers, and this study examined how a group of NY high school science teachers experienced their transition toward a more learner-centered classroom. This was done with the hope that it may inform future research and provide insights into the challenges teachers experience during reform efforts.

5.0 Organization of the Findings

The findings from this study pinpoint key challenges and supports that the participants faced as they tried to shift from their traditional teacher-centered approaches to more learner-centered approaches. In Chapter 4, all of the interpreted results are presented as they pertain to each of the research questions.

Chapter 5 is devoted to the discussion of these findings and describes the participants' transition toward more learner-centered teaching. The teachers' experiences of using the NGSS target practices, asking questions, and making their questions more sophisticated are discussed. The teachers' responses to the surveys and their interviews revealed the extent of their transition process and also identified those factors that facilitated or inhibited their transition. Chapter 5 concludes with a summary of the discussion.

Chapter 4: Findings

The findings are presented sequentially, corresponding to the sequence of the three research questions. Results for the first research question are presented as quantitative data. The second research question is analyzed with quantitative and qualitative data based on observations of the participants' professional practices. For the third research question, qualitative evidence is presented to address the factors that the participants reported as facilitating or inhibiting their transition from a teacher-centered approach to a learner-centered approach using the SEPs of the NGSS as a guide.

4.1 Research Question 1

1. What are the characteristics of teachers' transition from a traditional teacher-centered to a learner-centered approach following a professional development workshop with a focus on *Asking questions* and *Engaging in argument from evidence* from the phenomenological approach of the NGSS?

4.1.1 Participants' Transition From Teacher-Centered to Learner-Centered Practices

The results for the first research question that addressed the participants' transition from a teacher-centered to a learner-centered approach, based on classroom observations and the learner-centered rubric, are presented in Figures 1 through 5. The average frequency counts of the categories adapted from the rubric by Weimer (2013) for all four teacher participants across the nine observations are shown in Figure 1.

The data indicate higher average counts (orange bars in Figure 1) for a transitional approach (a mix of lecture and student engagement) compared to a learner-centered or teacher-centered approach. Observations 3 and 4 have the same low average frequency count (one occurrence) for teacher-centered, closely followed by Observation 8 (frequency = 1.5); hence, the teachers' classroom professional practice was largely transitional to learner-centered for the nine observations. Observations 3 and 8 had the highest learner-centered average frequency (7). It is noteworthy that there was no evidence of a continuous progression toward higher learner-centered frequencies during the nine observations.

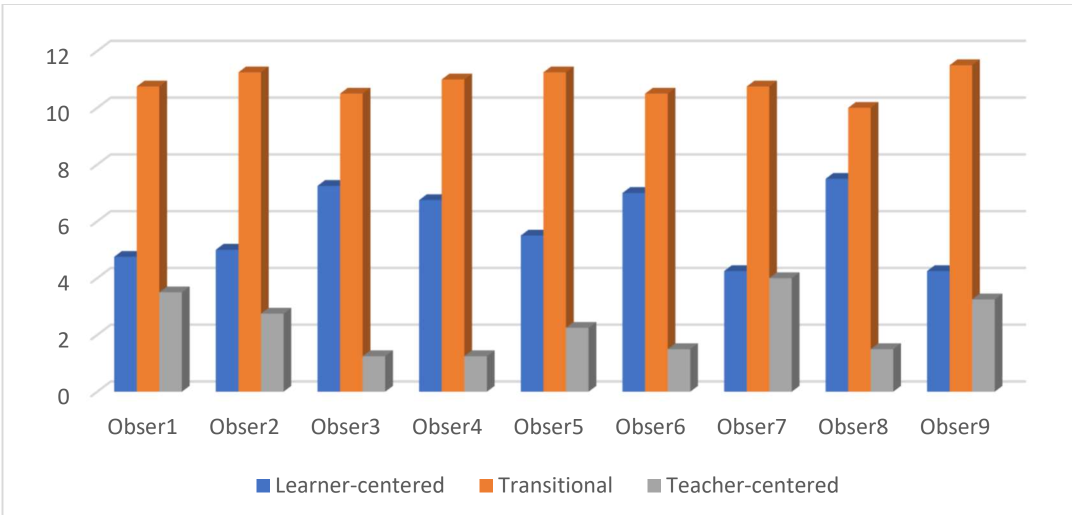

Figure 1: Average Frequencies. Average frequency for all rubric categories for all four participants.

As shown in Figure 1, Observation 7 had the highest teacher-centered frequency (grey bar), although modest (frequency of 4), followed by Observation 1 with the second-highest frequency (3.5). The data pattern in Figure 1 provided insight for the order of further analysis of the teachers' classroom observations (Figures 2–5). Given the strong trends in the transitional category's occurrence in the pattern of observations (Figure 1), the transitional category results guided the sequential organization of the four teacher participants' reported results. That is, the average transitional frequencies for each of the four teachers are presented, beginning with the highest transitional participant (Ellen) and ending with the lowest transitional participant (Kate), as shown in Table 2. The transitional frequency averages ranged from 13 to 9. The learner-centered the highest. The frequency averages ranged from 5 to 8, with Ellen having the lowest average and Kate teacher-centered frequency averages were in the range of 1 to 4.

Table 2: Average Frequency Counts. Average frequency counts (rounded to the next whole number) for the 9-weeks of observations for the rubric categories for the four participants.

Participant	Learner-Centered category	Transitional category	Teacher-Centered category
Ellen	5	13	1
Gwen	3	11	4
Carol	7	10	2
Kate	8	9	2

In terms of the transitional category, Ellen had the highest average (23), and Kate had the lowest average (9). For the learner-centered category, Kate had the greatest frequency (8); but Carol was a close second (7). Consequently, the individual teacher data results are given beginning with Ellen, followed by Gwen, Carol, and Kate. Overall, the difference in average frequency between the four participants varied from 0 to 5. For example, in Table 2, Carol's teacher-centered average is 2, and Kate's is 2, yielding a difference of zero. The largest difference is between Gwen's learner-centered average (3) and Kate's learner-centered average (8), resulting in a difference of 5.

4.1.2 Evidence of Participant's Teaching Practices During the Nine Observations

Figure 2 presents the observation frequencies for Ellen over the 9 weeks. The transitional category had the greatest frequency counts. Observation 7 had the highest value for the transitional category (16), and Observation 3 had the lowest value (8).

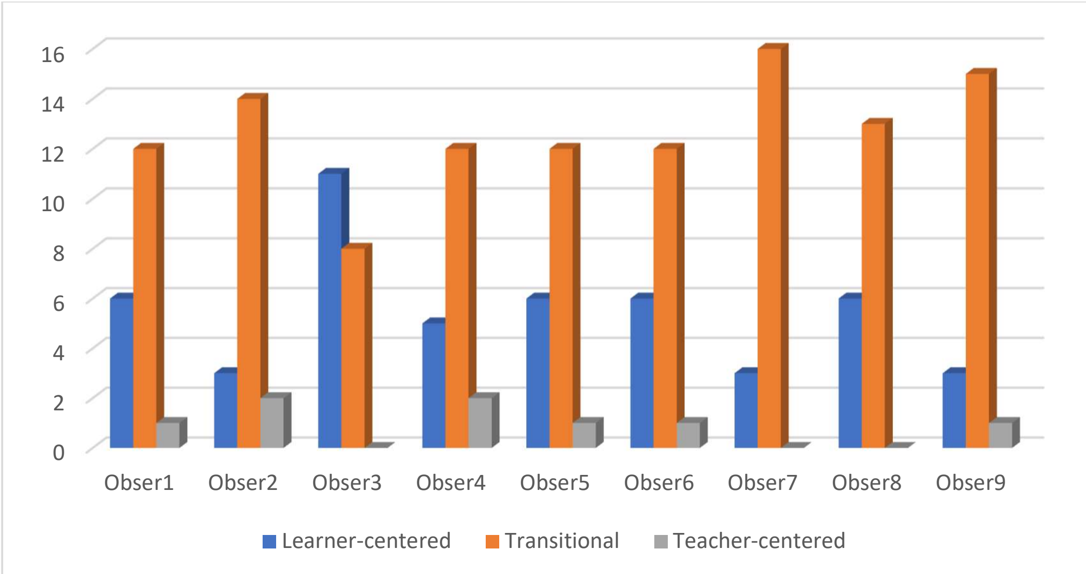

Figure 2: Ellen's Frequency Counts.

Interestingly, the learner-centered frequencies were comparable for Observations 1, 5, 6, and 8, with the average being 6. Observations 3, 7, and 8 had zero counts for the teacher-centered category. Observations 1, 5, 6, and 9 each had a teacher-centered count of 1, but Observationa 2 and 4 showed a frequency count of 2. Another finding was that the frequencies for the transitional category for Observations 1, 4, 5, and 6 had the same frequency count (12). The highest teachers' frequency values determined which lessons would be analyzed further to answer Research Question 2 regarding the teachers' transitional shifts. Lesson 1 was examined in more detail because it was the first lesson observed after the teachers' PD workshop. It provided a reference point against which to compare the other eight lessons. The results for Lessons 3 and 4 were further analyzed because they had the highest learner- and teacher-centered counts. Although Lessons 2 and 4 had similar counts, Lesson 2 was excluded because it immediately followed the reference point lesson (Lesson 1). Ellen had the highest transitional frequency (13) for the learner-centered rubric of all four participants (see Table 2). Ellen's average frequency counts for the learner- and teacher-centered categories were 5 and 1, respectively (see Table 2).

In Gwen's classroom, for the nine observed classes, Observation 2 had the highest transitional frequency (14), and the lowest frequency was for Observation 7 (9), as shown in Figure 3.

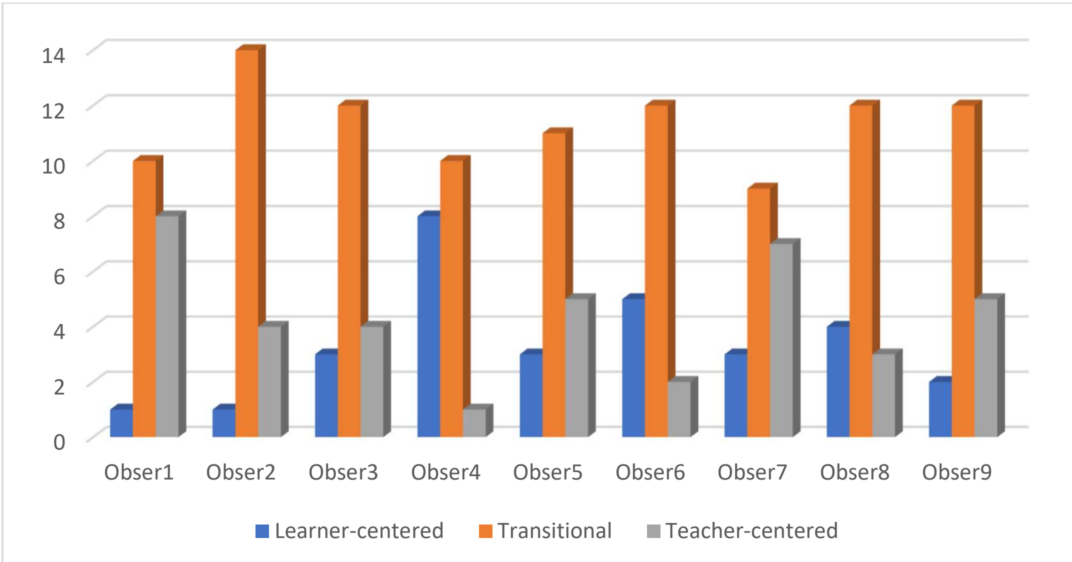

Figure 3: Gwen's Frequency Counts.

Gwen's frequency for the teacher-centered category had the highest value (8) at Observation 1. Her counts fluctuated over the 9-week period, and her next highest teacher-centered frequencies were for Observation 7 (7) and Observation 9 (5). Observation 4 had the highest learner-centered frequency (8), followed by Observation 6 (5) and Observation 8 (4). Observations 3, 5, and 7 all had a frequency of 3 for the learner-centered category, whereas Observations 1 and 2 had the same frequency count of 1. The highest frequencies for the learner-centered category and teacher-centered category were for Observations 4 (8) and 7 (7) (see Figure 3). Gwen had the second highest average transitional frequency count (11), as shown in Table 2. Gwen's average frequency for the teacher-centered category was 4, which was slightly higher than her average for the learner-centered category (3).

Carol's classroom observations showed strong evidence of transitional teaching practices for four of her nine observations (Observations 3, 4, 5, and 6), as shown in Figure 4.

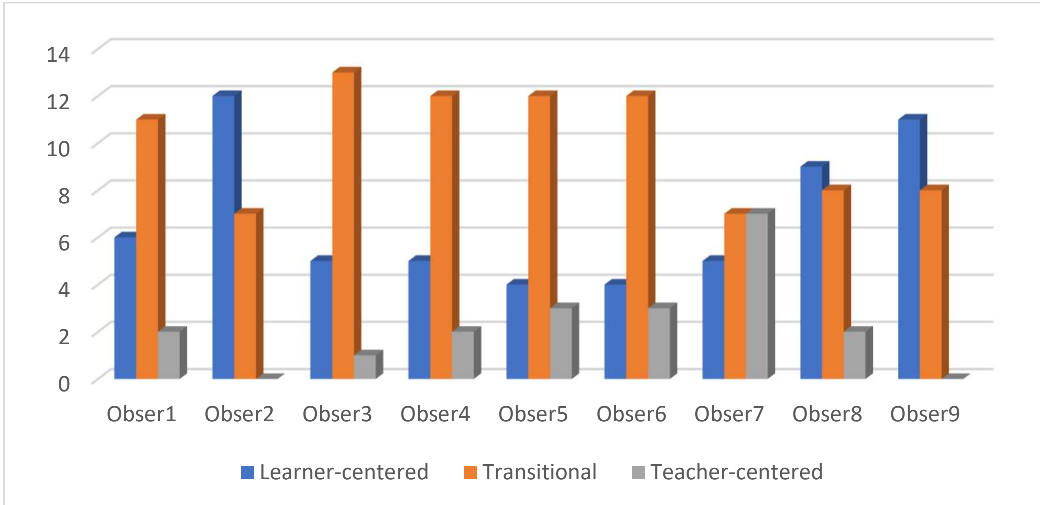

Figure 4: Carol's Frequency Counts.

Carol's frequencies for Observations 8 and 9 were both 8, whereas Observations 2 and 7 both had frequency counts of 7. Observation 1 had the third-highest value (11). The frequencies for the teacher-centered category varied from 0 to 3 for Carol's 9-week observations; except for Observation 7 (7). The highest frequency for the learner-centered category, excluding Observation 2, was for Observation 9 (11). However, Carol's frequencies were slightly lower than the frequencies for Ellen and Gwen for the transitional category. However, Carol had a higher frquency for the learner-centered category than Ellen or Gwen.

Lastly, of all the participants, Kate had the lowest frequency counts for the transitional category but the highest average for the learner-centered category. Kate's transitional frequency counts were 10 and 11, except for Observations 6 and 8 with frequencies of 6 and 7, respectively. For Observations 3 through to 6, Kate's frequencies for the teacher-centered category were all 0, but her average frequency for Observations 3 through 8 was 9.6 (see Figure 5).

In Observation 6, Kate's frequency for the learner-centered category was 13 (see Figure 5). Notably, this was the highest category count among the participants. After peaking in Observation 6, Kate obtained a frequency of 1 for the learner-centered category in Observation 9 (see Figure 5). Kate's Observation 9 also had the highest teacher-centered frequency count of 7. Kate had the least overall frequency count (9) for the transitional category but the highest average for the learner-centered category. The average 9-week frequency count for Kate's learner-centered category was 8 and for the teacher-centered category, her average was 2 (see Table 2).

In NYS, a student's score on the statewide Regents examination determines whether the student may graduate. Students' success on these exams is a determining factor for many school districts and teachers alike. Because the Regents examinations are so high stakes for the public high schools in NY, during the last few weeks before the exam it is customary for teachers to have highly structured, teacher-centered learning experiences to enhance the students' chances of performing well on these examinations. As a result, it is not surprising that all four participants showed an increase in their teacher-centered values for Lessons 8 and 9, the lessons taught during weeks of review for the June Regents examinations.

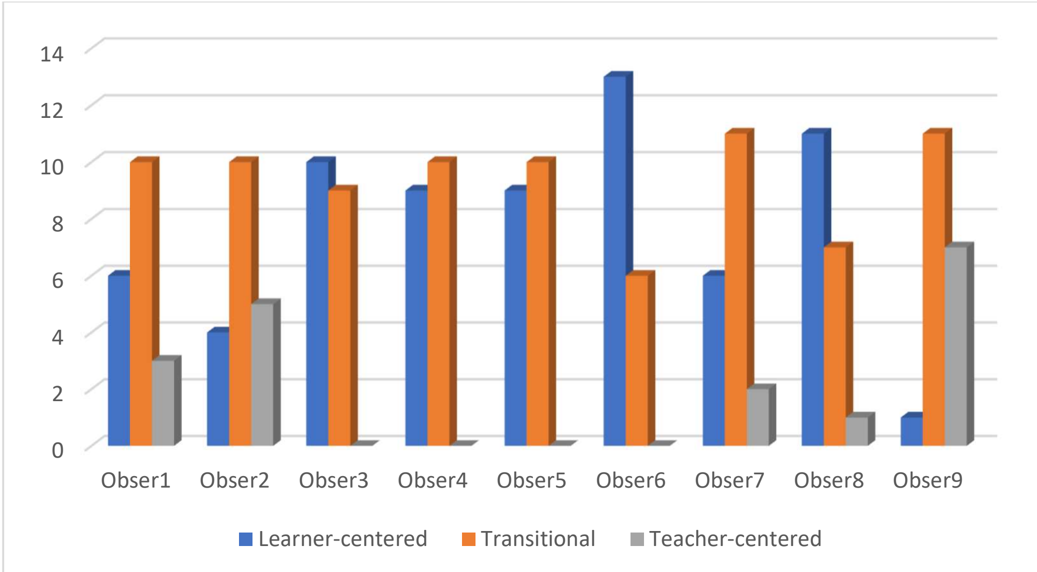

Figure 5: Kate's Frequency Counts.

4.1.3 Statistical Data Regarding the Classroom Practices Categories: Learner Centered, Transitional, and Teacher Centered

Table 3 presents the total frequencies for the learner-centered, transitional, and teacher-centered categories for all four participants. Frequency counts for the teacher-centered category came to 85, the learner-centered category came to 209, and the transitional category reached 390 –the largest value of all of the categories (see Table 3).

Table 3: Total Frequency Count for Each Category of Classroom Practices.

Participant	Learner-Centered category	Transitional category	Teacher-Centered category
Ellen	49	114	8
Gwen	30	102	39
Carol	61	90	20
Kate	69	84	18
Category total	209	390	85

The order of the participants in Table 3 is based on their value for the transitional category, with higher scores reported first. Ellen's transitional category total was 114, whereas

Kate had the lowest count (84). Gwen had the second highest count at 102, and Carol was at 94. There was a small difference of nine between Gwen's total frequency count for the teacher-centered category (39) and her total frequency count for the learner-centered (30) category. For the other participants, the differences between their teacher-centered and learner-centered totals were greater than 40. The difference between the two categories for Gwen was notably small.

A chi-square test was used to determine if there was a statistically significant difference among the total frequency counts for the three categories of learner centered, transitional, and teacher centered. In Table 4, the chi-square results for total category frequencies (from Row 5 of Table 3) are presented and are highly significant ($p \ll 0.01$). The differences between the total frequencies were not likely due to chance, indicating that the total frequency for the transitional category (390; Mean = 97.5, SD = 13.3) was significantly larger than the frequencies for the other two categories of learner centered and teacher centered (209 and 85, respectively; Mean = 52.25, SD = 16.95 and Mean = 21.25, SD = 12.94, respectively).

Table 3 shows the range of the frequency counts for the learner-centered, transitional, and teacher-centered categories. It appears that the participants' frequency counts for the transitional category were less variable than their frequencies for the learner-centered and teacher-centered categories. To determine if this was statistically significant, a chi-square test was used to examine patterns in the frequencies in each of the three columns of data in Table 3, and the text results are reported in Table 4. The calculated results show the frequencies for the learner-centered and teacher-centered categories ($p < 0.01$) were significantly different from one another. However, the frequencies for the transitional category were not significantly different ($p = 0.14$) from one another. This supports the conclusion that the teachers' use of the transitional classroom practices was more consistent than was their use of teacher-centered and learner-centered practices.

Table 4: Summary of Chi-Square Data of the total frequency counts for the Learner-centered, Transitional and Teacher-centered categories (Columns 1 to 3), including the Column totals (Row 5) in Table 3.

Source of data	Chi-Square value	Degrees of freedom	p-value
Learner-Centered frequencies (Column 1)	16.51	3	< 0.01
Transitional frequencies (Column 2)	5.45	3	0.14 (n.s.)
Teacher-Centered frequencies (Column 3)	23.66	3	< 0.01
Total frequencies (Row 5)	206.38	2	<< 0.01

Overall, the Chi-square data supports the prior bar graph results in this chapter. There was consistency among the four participants, and the differences in frequencies for the transitional classroom practices were not significantly different. However, there were statistically significant differences among the frequency counts for the other two categories. Although the sample was very small, the results are noteworthy. The statistical data describing the classroom practices categories complement the classroom observations of the learner-centered, teacher-centered, and traditional approaches noted on the researcher's frequency rubric charts.

4.2 Research Question 2

> What characterizes teachers' professional practice during their transition from a traditional teacher-centered to a learner-centered approach with respect to the phenomenological approach of the science and engineering practices of *Asking questions* and *Engaging in argument from evidence?*

Evidence from the rubrics and the coded transcripts from the four participating teachers' classroom observations was used to answer this research question. The rubrics showed the results from describing each 5-minute interval in a 40-minute class period. The evidence obtained using the first rubric (Tables 5, 7, 9, and 11) for each participant pertained to the NGSS practice of A*sking questions*. The second rubric pertained to the NGSS practice of *Engaging in argument from evidence* (Tables 6, 8, 10, and 12). This included the frequency of each practice during class observations. Using the DOK chart, I further coded the teachers' in-class lesson transcripts for three of their nine observations. The three selected classroom observations that I transcribed and coded were the first classroom observation, the observation with the highest teacher-centered frequency, and the observation with the highest learner-centered frequency, It is important to note that Observation 2 was not chosen because it was the next lesson immediately after the reference point lesson. This procedure allowed me to observe any patterns in the three lessons. The transcripts of the three selected observations for each participants were coded based on the four DOK levels of questioning, as shown in appendices G to R. The results are presented in sequential order for Ellen, Gwen, Carol, and Kate.

4.2.1 Results for Ellen

Table 5 summarizes the findings for Ellen, using the 40-minute rubric with 5-minute intervals for nine classroom observations. During these observations, I indicated on the rubric whether Ellen implemented at least one of the target practices during each 5-minute interval. The data in Table 5 represent the SEP of *Asking of questions*. Table 6 presents Ellen's data for the SEP of *Engaging in argument from evidence*. The row totals indicate questioning during a single observation, but the column totals give a summary of the 9-week observation period. An (x) in a rubric cell indicates that Ellen was observed expressing/fostering the given science practice during the particular interval in the 40-minute lesson. When Ellen was not observed expressing/fostering a given science practice, this was indicated with a minus (-).

Table 5 shows that for Ellen, the SEP of *Asking questions* was implemented during most of the intervals across her 40-minute class periods. The exception sto this were Observations 5 and 6. In addition, Observations 2 and 4 both possessed one interval with no questions being asked, and the row totals for these observations were 7. Ellen's Observations 5 and 6 had row totals of 6 and 2, respectively. Her other observations (Observations 1, 3, 7, 8, and 9) all had row totals of 8. During Observations 2, 4, and 6, Ellen did not ask questions during the first 5-minute interval. Questions during Observation 6 were only asked 11-20 minutes (the third and fourth intervals) into the lesson.

In contrast, Observations 1, 3, 7, 8, and 9 showed that Ellen asked questions during each of the 5-minute intervals. Throughout the nine weekly observations, Ellen asked questions in two to eight of the eight total intervals for each lesson. -Out of the 72 total intervals, Ellen asked questions during 62 of them.

Table 5: Ellen's Interval Data for the SEP of ***Asking Questions*.**

Time interval (mins)	#	1-5 min 1st	6-10 min 2nd	11-15 min 3rd	16-20 min 4th	21-25 min 5th	26-30 min 6th	31-35 min 7th	36-40 min 8th	Row total
Observed at least one instance of *Asking questions*	1	x	x	x	x	x	x	x	x	8
	2	-	x	x	x	x	x	x	x	7
	3	x	x	x	x	x	x	x	x	8
	4	-	x	x	x	x	x	x	x	7
	5	x	x	x	x	x	x	-	-	6
	6	-	-	x	x	-	-	-	-	2
	7	x	x	x	x	x	x	x	x	8
	8	x	x	x	x	x	x	x	x	8
	9	x	x	x	x	x	x	x	x	8
Column total		6	8	9	9	8	8	7	7	**62**

Note. x = the SEP of *Asking questions* was observed; - = the SEP of *Asking questions* was not observed.

Over the 9 weeks, for every observation, Ellen always asked questions during the third and fourth intervals. And except for Observations 5 and 6, most of Ellen's observations included *Asking questions* until the last 10 minutes of each class. The first 5-minute column total was 6, but the second, fifth, and sixth column totals were 8. The column totals over the 9 weeks showed a gradual increase then decrease from the first interval to the last interval with the total starting at 6 and increasing to 9 but then decreasing to 7.

Additional analyses are presented for the SEP of *Engaging in argument from evidence* (see Table 6). Over the 9-week observation period, Ellen had no substantial tallies for the use of *Argument from evidence*; the maximum number of 5-minute intervals with tallies was only three (Observation 5).

Table 6: Ellen's Interval Data for the SEP of *Engaging in Argument From Evidence*.

Time intervals (mins)	#	1-5 Mins 1st	6-10 Mins 2nd	11-15 Mins 3rd	16-20 Mins 4th	21-25 Mins 5th	26-30 Mins 6th	31-35 Mins 7th	36-40 Mins 8th	Row Totals
Observed at least one instance of *Argument from evidence*	1	-	-	-	-	x	x	x	-	3
	2	-	-	-	x	-	-	-	-	1
	3	-	-	x	x	-	-	-	-	2
	4	-	-	-	x	x	-	-	-	2
	5	-	-	x	x	x	-	-	-	3
	6	-	-	-	-	-	-	-	-	0
	7	-	-	-	-	x	x	-	-	2
	8	-	-	-	-	x	-	-	-	1
	9	-	-	-	-	-	-	-	-	0
Column totals		0	0	2	4	5	2	1	0	**14**

Observations 6 and 9 showed little evidence for the practice of *Engaging in argument from evidence*. It is important to note that what evidence was found to support the SEP of *Engaging in argument from evidence* was found mainly during the fourth and fifth intervals. The number of intervals in which *Engaging in argument from evidence* was observed was 14 (out of 72 total intervals).

Overall, there seems to be greater consistency in the practice of *Asking questions*, with a total of 62 intervals–four times more than for the practice of *Engaging in argument from evidence*. The majority of these two SEPs were observed during the third, fourth, and fifth intervals, which were around the midpoint of the observation period.

4.2.2 Qualitative Evidence for Ellen

Further results from the qualitative evidence are presented for Ellen, who taught ninth-grade Earth science to her English Language Learner students and for whom English was her second language. Qualitative evidence includes questions Ellen asked during her observed lessons. Examples of these questions from the her Lesson 1 reference point (see Appendix G), her highest rated learner-centered lesson (see Appendix H), and her highest rated teacher-centered lesson (see Appendix I) are provided. The teacher's questions were coded using Webb's DOK (Hess 2005, 2010; Hess et al., 2009; (see Appendix D) .For the three observations chosen, I coded the questions Ellen asked during those observations using Webb's DOK to guide the coding process.

For Ellen's first observation, her questions represented three of the four levels of questioning. Level 4, extended thinking, was not observed during Observation 1. For Observation 1, as the class started, Ellen used mainly Level 1 recall and reproduction questions. Most of Ellen's Level 1 questions began with, "What is . . ." and "Define. . . ." These questions were usually responded to with a rote response or recall of a fact or definition. If no response was offered, she would repeat the question with slight variation. For example, "Define a revolution" would be followed with "What does a revolution mean?" and "What is Jovian made of ?" would be followed by, "What is different?" (see Appendix H). For Observation 1, the reference point, there were 12 Level-1 questions throughout the lesson, nine Level-2 questions, five Level-3 questions, and no Level-4 questions during this observation. During Observation 3, Ellen's highest learner-centered lesson, she was observed asking seven Level-1 questions, eight Level-2 questions, seven Level-3 questions, and zero Level-4 questions. This result indicates that Ellen began to ask more questions that required students to use strategic thinking and apply skills and concepts. For example, the question, “What is the equinox?” may seem like a recall question, but the students needed to demonstrate their response on their globe. Therefore, this question was considered a Level-2 question (see Appendix D). Observation 4 was Ellen’s highest teacher-centered lesson (see Figure 2). There were seven Level-1 questions, three Level-2 questions, and four Level-3 questions. This lesson had fewer questions asked of students than during Observation 3. This may have been due to the fact that Ellen often rephrased questions during Observation 4, and a rephrased question could have been coded at a different level. For example, one of her Level-2 questions on evaporation was rephrased to include a specific example and became a Level-3 question about the evaporation/cooling process. This rephrasing was observed in all of the participants’ classes as the teachers tried to encourage their students to be more engaged in the class.

4.2.3 Results for Gwen

The data that characterize Gwen’s transition are presented in Tables 7 and 8 and summarize her use of the two target SEPs (i.e., *Asking questions* and *Engaging in argument from evidence*) over the 9 week observation period. For Observations 1 and 3, Gwen asked at least one question during each 5-minute interval (see Table 7). During Observations 2, 4, 5, and 8, Gwen was observed engaging in the SEP of *Asking questions* in seven of the eight intervals for each observation. She engaged in this same SEP during six of the eight intervals for Observations 6 and 9, and Observation 7 had five intervals with the observed SEP. Over the 9 weeks of observations, Gwen consistently demonstrated the target SEP during the fifth through seventh intervals (at 21 to 35 min into the class).

Table 7: Gwen's Interval Data for the SEP of ***Asking Questions*.**

Time intervals (Mins)	#	1-5 Mins 1st	6-10 Mins 2nd	11-15 Mins 3rd	16-20 Mins 4th	21-25 Mins 5th	26-30 Mins 6th	31-35 Mins 7th	36-40 Mins 8th	Row Totals
Observed at least one instance of *Asking questions*	1	x	x	x	x	x	x	x	x	8
	2	x	x	-	x	x	x	x	x	7
	3	x	x	x	x	x	x	x	x	8
	4	-	x	x	x	x	x	x	x	7
	5	x	-	x	x	x	x	x	x	7
	6	-	x	-	x	x	x	x	x	6
	7	-	-	x	-	x	x	x	x	5
	8	-	x	x	x	x	x	x	x	7
	9	x	-	x	x	x	x	x	-	6
Column totals		5	6	7	8	9	9	9	8	**61**

The data for the first 15 minutes of Gwen's classes (intervals 1 through three; see Table 7) showed a total column count of five, six, and seven, respectively. For four of the nine observations (rows in Table 7), no questions were asked during the first 15 minutes of the class. In addition, three observations (5, 7, and 9) had no questions asked during the second interval, and two observations (2 and 6) had no questions asked during the third interval. Gwen's peak of questioning occurred after the third interval for all nine observations, and she was observed engaging in the SEP of *Asking questions* for 61 of the 72 total intervals.

The evidence in Table 8 shows fewer tallies for the SEP of *Engaging in argument from evidence* than for *Asking questions*. Over the 9 weeks, intervals four and five showed the highest tallies of seven and six, respectively. The first and last intervals had no tallies; the second and seventh intervals had only one tally; and the third and sixth intervals had counts of 2 and 3, respectively (see Table 8).

Table 8: Gwen's Interval Data for the SEP of ***Engaging in Argument From Evidence.***

Observation number (#) and minute time intervals (Mins)	#	1-5 Mins 1st	6-10 Mins 2nd	11-15 Mins 3rd	16-20 Mins 4th	21-25 Mins 5th	26-30 Mins 6th	31-35 Mins 7th	36-40 Mins 8th	Row Totals
Observed at least one instance of *Argument from evidence*	1	-	-	-	x	x	-	-	-	2
	2	-	-	-	x	-	-	-	-	1
	3	-	x	x	-	-	-	-	-	2
	4	-	-	-	x	x	x	-	-	3
	5	-	-	-	x	x	-	-	-	2
	6	-	-	-	x	x	x	x	-	4
	7	-	-	-	-	x	x	-	-	2
	8	-	-	x	x	-	-	-	-	2
	9	-	-	-	x	x	-	-	-	2
Column totals		0	1	2	7	6	3	1	0	**20**

Observation 6 had the most consecutive intervals during which Gwen's students demonstrated the target SEP of *Engaging in argument from evidence.* This occurred in the fourth through seventh intervals, for a total time of 20 minutes, comprising half of the lesson period. The second-longest consecutive intervals in which Gwen's students demonstrated *Engaging in argument from evidence* was for three intervals, a total of 15 minutes, for Observation 4. All other observations showed shorter involvement in *Engaging in argument from evidence*, only for a total time of 10 minutes or two intervals (see Table 8) except for Observation 2 with a single 5-minute interval. The peak in classroom argumentation mainly occurred after 15 minutes into each class and subsided after 25 minutes into each class. The patterns for Gwen's class in terms of engagement in the two SEPs were similar, in that most of the tallies occurred mid-lesson (during the fourth and fifth intervals). Overall, Gwen was observed engaging in the target SEP of *Asking questions* during 61 of the 72 intervals, and her students were observed engaging in the target SEP od *Engaging in argument from evidence* during 20 of the 72 intervals. It is noteworthy that over the 9 weeks Gwen was observed engaging in the SEP of *Asking questions* during 85% of the intervals, but the same lessons showed far less *Engaging in argument from evidence* (29%).

4.2.4 Qualitative Evidence for Gwen

Qualitative evidence in the form of illustrative quotations drawn from the transcripts of Gwen's observed classes is presented for her Lesson 1 reference point (see Appendix J), her most highly rated learner-centered lesson (see Appendix K), and her most highly rated teacher-centered lesson (see Appendix L). These questions were coded using the methods in AppendixD.

Gwen's reference point observation showed 20 Level-1 questions, three Level-2 questions, and one Level-3 question (see Appendix J). Interestingly, for Observation 1, Gwen asked a Level-3 question during the first 5-minute interval. Level-1 questions were mainly asked during the second through the eighth interval, and Level-2 questions were mostly posed midway through each lesson (i.e., fourth through the sixth interval). In Observation 4, the most highly rated learner-centered lesson, Gwen's questions were primarily Level 2, 3, and4. There was one Level-1 question, eight Level-2 questions, 10 Level-3 questions, and four Level-4 questions–for a total of 23 questions. During Observation 7, the most highly rated teacher-centered lesson, there were fewer questions overall (12 questions total), and these questions were coded as Level-1 (7 questions), Level-2 (four questions), and Level-3 (one question). Of the three observations, Observation 4 (the most highly rated learner-centered lesson) had the most Level-2, Level-3, and Level-4 questions.

4.2.5 Results for Carol

Table 9 summarizes Carol's interval data regarding the SEP of *Asking questions*. Observations 2, 3, and 6 had at least one question asked during each 5-minute interval for the entire lesson. Observation 9 showed a tally of seven. There were six tallies each for Observations 1 and 8 and five tallies for Observation 5. Both Observations 4 and 7 had tally totals of four (see Table 9). For Observation 4, no questions were asked for the last 20 minutes of the lesson, and this was due to the fact that the students were working on an assignment. There were also no tallies for the last 15 minutes of Observation 5.

Table 9: Carol's Interval Data for the SEP of ***Asking Questions*.**

Time intervals (Mins)	#	1-5 Mins 1st	6-10 Mins 2nd	11-15 Mins 3rd	16-20 Mins 4th	21-25 Mins 5th	26-30 Mins 6th	31-35 Mins 7th	36-40 Mins 8th	Row Totals
Observed at least one instance of *Asking questions*	1	-	x	x	x	x	x	x	-	6
	2	x	x	x	x	x	x	x	x	8
	3	x	x	x	x	x	x	x	x	8
	4	x	x	x	x	-	-	-	-	4
	5	x	x	x	x	x	-	-	-	5
	6	x	x	x	x	x	x	x	x	8
	7	x	-	-	x	x	-	x	-	4
	8	x	x	-	-	x	x	x	x	6
	9	x	x	x	x	x	x	x	-	7
Column totals		8	8	7	8	8	6	7	4	**56**

The column totals in Table 9 show that Carol was observed engaging in the SEP of *Asking questions* more often during the first, second, fourth, and fifth intervals than during the other intervals over the 9 weeks. The third and seventh intervals were the second highest, with a count of seven each. The third and seventh intervals were the second highest, with a count of seven each. During the final interval, Carol was observed engaging in the target SEP less frequently. Of the total 72 intervals, Carol was observed engaging in *Asking questions* for 56 of those intervals, which is 78%.

Carol's data for the SEP of *Engaging in argument from evidence* are presented in Table 10. Her data are relatively sparse with the target SEP not being observed in many of her classes. Five of the nine class observations showed no engagement in the SEP (i.e., Observations 1, 2, 4, 6, and 9).

Table 10: Carol's Interval Data for the SEP of ***Engaging in Argument From Evidence*.**

Observation number (#) and minute time intervals (Mins)	#	1-5 Mins 1st	6-10 Mins 2nd	11-15 Mins 3rd	16-20 Mins 4th	21-25 Mins 5th	26-30 Mins 6th	31-35 Mins 7th	36-40 Mins 8th	Row Totals
Observed at least one instance of *Argument from evidence*	1	-	-	-	-	-	-	-	-	0
	2	-	-	-	-	-	-	-	-	0
	3	-	x	x	x	x	x	x	x	7
	4	-	-	-	-	-	-	-	-	0
	5	-	-	x	x	-	-	-	-	2
	6	-	-	-	-	-	-	-	-	0
	7	x	x	-	x	-	x	-	-	4
	8	x	x	x	x	x	x	x	x	8
	9	-	-	-	-	-	-	-	-	0
Column totals		2	3	3	4	2	3	2	2	**19**

Observation 8 had a tally for each 5-minute interval during the 40-minute lesson, and Observation 3 had seven tallies with an omission for the first 5 minutes. Observation 7 had tallies for the first, second, fourth, and sixth intervals. There were only two tallies for Observation 5. Table 10 shows that interval 4 (around the midpoint) had the highest column total (4) for *Engaging in argument from evidence* over the 9 weeks. The second-highest count of three was found in Intervals 2, 3, and 6. Lessons 3, 5, 7, and 8 were the only ones with tallies.

To summarize, of the 72 total intervals, Carol was observed demonstrating the SEP of *Engaging in argument from evidence* in 19 of them. Observations 3 and 8 had the most tallies of 7 and 8, respectively (see Table 10). For the SEP of *Asking questions*, six of Carol's nine observations had tallies of 6 or more, and she engaged in the target SEP during 78% of the intervals.

4.2.6 Qualitative Evidence for Carol

Qualitative evidence is presented based on the transcripts of Carol's recorded classes. Illustrative questions from her Lesson 1 reference point (see Appendix M), her most highly rated learner-centered lesson (see Appendix N), and her most highly rated teacher-centered lesson (see Appendix O) are presented in the appendices. These questions were coded based on the method in Appendix D.

Carol's lessons chosen for particular attention were Observations 1, 7, and 9. For Observation 1, Carol asked a total of 11 questions during the 40-minute lesson. The questions ranged from Level 1 to Level 3. There were six Level-1 questions, three Level-2 questions, and two Level-3 questions. There were no Level-4 questions involving extended thinking. However, Observation 9 had a number of questions at all four levels. These questions and other lesson elements were sufficient to render this ninth observation as Carol's highest learner-centered lesson over the 9 weeks. During Lesson 9, Carol asked eight Level-1 questions (involving recall and reproduction), two Level-2 questions (involving application of skills and concepts), four Level-3 questions (involving strategic thinking), and four Level-4 questions (involving extended thinking; see Appendix N). In Carol's highest rated teacher-centered observation (Observation 7), there were fewer questions overall. There were four Level-1 questions, one Levle-2 question, six Level-3 questions, and no Level-4 questions (see Appendix O). Overall, Carol's lessons were characterized by her frequency of questioning and their levels. She was able to ask a number of Level-3 and Level-4 questions. Although Carol had a high level of questioning, her students'frequency of argumentation within the classroom was low.

4.2.7 Results for Kate

The data for Kate are presented in Tables 11 and 12.

Table 11: Kate's Interval Data for the SEP of ***Asking Questions*.**

Observation number (#) and minute time intervals (min)	#	1-5 Mins 1st	6-10 Mins 2nd	11-15 Mins 3rd	16-20 Mins 4th	21-25 Mins 5th	26-30 Mins 6th	31-35 Mins 7th	36-40 Mins 8th	Row Totals
Observed at least one instance of *Asking questions*	1	x	x	x	x	x	x	x	x	8
	2	x	x	-	-	x	x	x	x	6
	3	x	x	x	x	x	x	x	x	8
	4	x	x	x	x	x	x	x	x	8
	5	x	x	x	x	x	x	x	x	8
	6	-	x	x	x	x	x	x	x	7
	7	x	x	x	x	x	x	x	x	8
	8	x	x	x	x	x	x	x	x	8
	9	x	-	x	x	x	-	-	-	4
Column totals		8	8	8	8	9	8	8	8	**65**

Most of Kate's observations had a tally indicating that she asked at least one question during that interval. During Observations 2, 6, and 9, Kate did not ask a question during at least one interval. Observation 2 had six tallies, none in the third and fourth interval. Observation 6 had seven tallies for the second through the eighth intervals, and Observation 9 had four tallies (see Table 11). Among the four questions asked during Observation 9, the last question was asked during the fifth interval, during minutes 21-25 of the class period. The column totals for each interval over the 9 weeks were rather consistent: mainly 8 and one 9. The fifth interval had the greatest number of tallies (9), and all of the other intervals had eight. Interestingly, there were only three lessons (Observations 2, 6, and 9) that had intervals during which no questions were asked. In contrast, there are very few tallies for Kate's students being observed *Engaging in argument from evidence* (see Table 12).

Table 12: Kate's Interval Data for the SEP of ***Engaging in Argument From Evidence.***

Observation number (#) and minute time intervals (min)	#	1-5 Mins 1st	6-10 Mins 2nd	11-15 Mins 3rd	16-20 Mins 4th	21-25 Mins 5th	26-30 Mins 6th	31-35 Mins 7th	36-40 Mins 8th	Row Totals
Observed at least one instance of *Argument from evidence*	1	-	-	-	x	x	-	-	-	2
	2	-	-	-	x	-	-	-	-	1
	3	-	x	x	-	-	-	-	-	2
	4	-	-	-	x	x	x	-	-	3
	5	-	-	-	x	x	-	-	-	2
	6	-	-	-	-	x	x	-	-	2
	7	-	-	-	x	x	x	x	-	4
	8	-	-	x	x	-	-	-	-	2
	9	-	-	-	x	x	-	-	-	2
Column totals		0	1	2	7	6	3	1	0	**20**

Each of the nine observed lessons had at least one tally documenting that Kate's students were observed *Engaging in argument from evidence*, but the maximum number of tallies recorded for a single lesson was four. There were no instances of *Engaging in argument from evidence* observed during the first or last intervals of the nine observed lessons; however, when this SEP was observed it was usually around the fourth and fifth intervals. Interval 4 had the highest column total of 7. The fifth interval had a column total of 6, the sixth interval had a total of 3, the third interval had a total of 2, and the seventh and second intervals each had a total of 1. The observed row totals of tallies for the nine lessons varied from 4 to 1. Observation 7 had the highest tally count of 4. It is important to note that most of the observed *Engaging in argument from evidence* occurred after 15 minutes into each lesson.

In general, Kate's column totals from Tables 11 and 12 show the SEP of *Asking questions* was observed to occur three times more often than the SEP of *Engaging in argument from evidence* during the 9-week observation period.

4.2.8 Qualitative Evidence for Kate

Qualitative evidence from the transcripts of Kate's observed lessons is presented for the following lessons: Lesson 1 reference point (see Appendix P), most highly rated learner-centered lesson (see Appendix Q), and most highly rated teacher-centered lesson (see Appendix R). Evidence is presented as illustrative quotations drawn from each of the respective lessons. The questions Kate asked were coded using the method presented in Appendix E

Kate's Observation 1 had 27 Level-1 questions. However, there were only six Level-2 questions, one Level-3 question, and no Level-4 questions (see Appendix P). Of Kate's three observations that were analyzed, Observation 1 had the most questions that were notable. Kate's most highely rated learner-centered lesson (Observation 6), had fewer questions overall in comparison with Observation 1. It is noteworthy that Kate's questioning during her learner-centered lesson was remarkably less than that of the other participants during their most highly rated learner-centered lessons. Observation 6 had five Level-1 questions, six Level-2 questions, one Level-three question, and no Level-4 questions (see Appendix Q). Her most highly rated teacher-centered lesson, Observation 9, had nine questions total. Five Level-1 questions and three Level-2 questions.

As a researcher observer in the classroom, it was apparent that Kate used mainly Level-1 questions to encourage her students, who primarily worked in small groups. For example, in Observation 6, Kate asked the following:

> What else do you think is changing? You told me height. That's good. You told me the bones. Yes. What else? What do you think is happening here?

During Observation 1, she asked, "What can you tell me about the reproductive cells, the sex cells, the gametes? What can you tell me about them?" Here, her questioning was intended to foster interaction between students.

4.2.9 Summary of Qualitative Evidence on the Level of Questioning

For comparative purposes, a summary table (see Table 13) is presented that lists the total frequency of occurrence for each level of questioning that was observed during each participant's three identified lessons. For example, in Table 13, Kate exhibited the most Level-1 questions (30) and Carol the least (18). Gwen had the second-highest number of Level-1 questions (28), and Ellen had the next highest number (26). For Level-2 questions, Ellen had the highest number (20), Gwen and Kate both had the second highest number (15), and Carol had the least (6). However, Carol and Gwen both had the highest number of Level-4 questions (4) and the second-highest number of Level-3 questions (12). Thus, the number of questions asked decreased as the level of questioning increased. Level-1 had 102 questions, Level 2 had 56, and Levels 3 and 4 had 40 and 8, respectively.

Table 13: Number of Questions Asked at Each Level by Each Teacher Across Their Three Identified Lessons.

	Level 1	Level 2	Level3	Level 4
Ellen	26	20	13	0
Gwen	28	15	12	4
Carol	18	6	12	4
Kate	30	15	3	0
Total	102	56	40	8

Level-3 and Level-4 questions are more strategic and involve extended thinking expressed by drawing conclusions, explaining phenomena, and analyzing or applying concepts. It is interesting to note that of the nine observations analyzed for each participant, Ellen and Kate had zero Level-4 questions, but Gwen and Carol both had four. Table 13 gives a concise synopsis of the number of questions asked at each level across the three identified lessons (Lesson 1 reference point and most highly rated learner- and teacher-centered lessons). Whereas, Table 14 shows the number of questions asked at each level across all nine observed lessons. Levels 2 through 4, which represent more learner-centered instruction, were the highest for Ellen (94), followed by Gwen (87), Kate (65), and Carol (46).

Table 14: Number of Questions at Each Level Asked by Each Participant Across the Nine Observations.

Participant	Level 1	Level 2	Level 3	Level 4	Row Totals –Level (Levels 1, 2, 3 and 4)
Ellen	121	63	29	2 **(94)**	215
Gwen	102	55	26	6 **(87)**	189

(continued).

Table 14 (continued): Total frequency of questions (Levels 1 to 4) used by each teacher participant for all nine lessons (continued).

Participant	Level 1	Level 2	Level 3	Level 4	Row Totals –Level (Levels 1, 2, 3 and 4)
Carol	49	24	16	6 **(46)**	95
Kate	73	42	20	3 **(65)**	138
Column total	345	184	91	17	637

Note. Entries in bold indicate the sum of Level-2, Level-3, and Level-4 questions.

4.3 Research Question 3

What factors do teachers identify as facilitating or inhibiting their ability to transition from a traditional teacher-centered to a learner-centered approach with respect to *Asking questions* and *Engaging in argument from evidence* from the phenomenological approach of engaging in the science and engineering practices?

To answer this question, I used Hayes et al.'s (2016) SIPS instrument. I adapted the survey to capture the participants' self-assessment of the frequency with which they and their students engaged in the target SEPs, and I used this frequency data to examine changes in their practices over the 9-week observation period. In addition, I interviewed the participants at Week 4 and Week 9 about their experiences transitioning to a learner-centered classroom.

4.3.1 Ellen's Frequency Results

Table 15 shows Ellen's assessment of the frequency with which her students engaged in the target science practices at two points during the 9-week observation period. At Week 4, halfway through the observation period, Ellen rated her students as rarely engaging in 14 of the 19 target science practices. However, by the end of the observation period, she rated her students as sometimes engaging in 12 of the practices and often engaging in five of the practices. By the end of the 9 weeks, Ellen judged her students as engaging more frequently in all of the target science practices, except for the practice related to creating a physical model of a scientific phenomenon (Item 13). In her interviews, Ellen described Item 13 as being more of a project-based assignment that required time for the students to fully conceptualize the unit and its related phenomenon and to make individual designs. It is important to note that Ellen did not rate her students as engaging in any of the science practices on a daily basis.

Table 15: Ellen's Report of the Frequency With Which Her Students Engaged in the Target Science Practices.

How often do your students do each of the following in your science class?	Never in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the last 30 days)	Often (three times a week in the past 30 days)	Daily (four or five times a week in the past 30 days)
1. Generate questions or predictions to explore		M	F		
2. Identify questions from observations of phenomena		M		F	
3. Choose variables to investigate (such as in a lab setting)	M	F			
4. Make and record observations		M	F		
5. Gather quantitative or qualitative data			M	F	
6. Organize data into charts or graphs			M	F	
7. Analyze relationships using charts or graphs		M	F		
8. Analyze results using basic calculations			M	F	
9. Write about what was observed and why it happened		M	F		
10. Present procedures, data, and conclusions to the class (either informally or formally)		M	F		
11. Read from the science textbook or other handouts in class		M	F		

(Continued).

Table 15: Ellen's Self-Report of the frequency with which Her students engaged in the Target Science Practices.

How often do your students do each of the following in your science class?	Never in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the last 30 days)	Often (three times a week in the past 30 days)	Daily (four or five times a week in the past 30 days)
12. Critically synthesize information from different sources (i.e., text or media)		M	F		
13. Create a physical model of a scientific phenomenon (like creating a representation of the solar system)		M F			
14. Use models to predict outcomes			M	F	
15. Explain the reasoning behind an idea		M	F		
16. Respectfully critique each other's reasoning		M	F		
17. Supply evidence to support a claim or explanation		M	F		
18. Consider alternative explanations		M	F		
19. Make an argument that supports or refutes a claim		M	F		

Not. M = midpoint survey (Week 4) and F = final survey (Week 9).

When rating her own science teaching at Week 4, Ellen described herself as often engaging in half of the target science practices (see Table 16). In addition, she rated herself as engaging in one practice (i.e., using science vocabulary) on a daily basis. Unlike her ratings of her students, she only rated half of her practices as becoming more frequent from Week 4 to Week 9. The greatest increase in frequency was for discussing students' prior knowledge or experience (Item 7), and no change from Week 4 to Week 9 was noted for five items (Items 1, 3, 4, 5, and 9). However, Item 4 was already rated as being performed on a daily basis at Week 4 and could not be rated any higher.

Table 16: Ellen's Self-Report of the Frequency With Which She Engaged in the Target Science Practices.

How often do you do each of the following in your science instruction?	Never in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times a week in the past 30 days)	Daily (four or five times a week in the past 30 days)
1. Provide direct instruction to explain a science concept				**M F**	
2. Demonstrate an experiment and have students watch				**M**	**F**
3. Use activity sheets to reinforce skills or content				**M F**	
4. Go over science vocabulary					**M F**
5. Apply science concepts to explain natural events or real-world situations				**M F**	
6. Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)			**M**	**F**	
7. Discuss students' prior knowledge or experience related to the science topic or concept		**M**		**F**	
8. Use open-ended questions to stimulate whole class discussions (most students participate)			**M**	**F**	
9. Have students work with each other in small groups				**M F**	
10. Encourage students to explain concepts to one another			**M**	**F**	

Note. M = midpoint survey (Week 4) and F = final survey (Week 9).

4.3.2 Ellen's Midpoint and Final Interview Results

Ellen was interviewed halfway through the observation period and at the end of the observation period regarding the factors that she believed hindered or facilitated her transition to a learner-centered classroom. Ellen was qualified in her teaching area and as an ENL teacher and taught Grades 10-12. Ellen had taught English as a second language to nonhonors Regents Earth science students for 4 years but was not a tenured teacher. Ellen noted that although she went back to school in 2014 for her master's degree, her first formal introduction to the NGSS SEPs was at the workshop I presented to the participants at the start of this study: “Well, the experience has been with you mostly. I feel like you got me introduced to it.”

4.3.2.1 Facilitating Factors

With respect to facilitating factors, at the 4-week point, Ellen was not confident in her transition to the learner-centered approach. She described her participation in this study as her first real exposure to the NGSS and questioned her ability to implement the target practices: “But I don’t feel like I really did it all the way.” However, at the 9-week point, Ellen identified support as the main factor that facilitated her transition to learner-centered teaching. Ellen was delighted with the online support available from the NYSSLS website and was pleased that she could receive ongoing support after her participation in this study. Ellen described how at the start of the observation period, a lesson was taking her an entire day to plan, which was not sustainable. However, with continued support, she was developing the ability to design lesson plans in a more reasonable period of time. In addition, Ellen described needing support related to facilitating group work, which she initially worried could result in her losing control over her students and their learning:

> I feel like I’m . . . so I like group work, but sometimes, like when you came sometime they all doing the . . . I mean they are working on what they should be working, but I feel like you losing the control.

Ellen also described how important the support of her administration was and how this support manifested in her being able to obtain the equipment she needed for lab sessions:

> But I feel like also . . . every time I ask him [the science department chair] can I get different equipment he would get it. For example, for next year, we are ordering a seismogram, seismograph sorry. So, then I can have the equipment.

4.3.2.2 Inhibiting Factors

At the midpoint of the observation period, Ellen's main concern was that she believed she needed more time to properly and thoroughly implement the science practices. She noted that what she was taught during her student teaching differed from the NGSS SEPs. As such, she believed that due to her lack of experience and limited planning time, she could not fully implement the target science practices as presented during the PD: "I didn't feel I did it 100% because I needed more time to prepare my lesson plans." Although Ellen repeatedly spoke of her uncertainty as to whether she was implementing the science practices properly, she extended the learner-centered approach to her other science classes:

> I don't think I did . . . the argumentation tool, I liked it. I actually did it with my ocean class, but I felt like I didn't really do it too much. I mean I did ask them questions and asked them for when they would answer it for like . . . and if they can explain why and give me evidence from it, but I feel like I was, I don't think I did it 100%.

By the end of the 9 weeks, Ellen was still concerned that there wasn't enough time to prepare for and implement the target practices:

> Well, I don't really think I'm doing NGSS. I mean, I do try to do the questioning and all that, but I guess I'll do it a little bit. Depends on the unit, to be honest. Some units are easy, and some . . . like the weathering is easy, you can talk about rivers cause you can show them videos or do it on the stream table so they can see it. Well, if they can see it's easy, if they can't see it's not. If it's not a visual, like earthquakes, it's more difficult to do NGSS, but the more real-world applications, the better with NGSS.

She was specifically concerned about students having enough time to describe their concept/phenomenon given that scientists are experts take a great deal of time to explain their theories:

> Yeah, like the Big Bang Theory, you know Einstein, people are coming up with, those are scientists have been doing it their whole life, and I don't know how you want the students to just come up with the thing model. You know?

She was also concerned about the low level of argumentation from evidence that was occurring in her classroom. At the end of the 9 weeks, Ellen identified two additional factors that inhibited her progress: preparing for the upcoming Regents Examinations and having to share a classroom. The time Ellen and her students needed to prepare for the Regents Exam left even less time for planning and implementing the target changes:

> Well, one of the concerns, the main one, is the Regents because I feel like we did it so close to the end that I was worried for the Regents and getting them ready.

Because Ellen shared her physical classroom space with another teacher, this prevented her from setting up her demonstrations in advance, which also took time away from the class:

> I wish I had my own room basically. Yeah, and then not have to run in the room and try to set it up and then . . . I just like to be organized and ready. I feel it will help because I could do whatever I wanted on the wall.

4.3.3 Gwen's Frequency Results

Table 17 shows Gwen's survey responses for how frequently she believed her students engaged in the target science practices. At the 4-week point, Gwen rated five of the 19 target science practices as rarely occurring, seven as occurring sometimes, and eight as occurring often. She didn't rate any of the target science practices as not occurring or occurring daily. At the end of the observation period, Gwen rated 11 of the 19 practices as occurring more frequently than at Week 4. The biggest increase in frequency from Week 4 to Week 9 was recorded for Items 1 (generate questions or predictions to explore) and 7 (analyze relationships using charts or graphs).

Table 17: Gwen's Report of the Frequency With Which Her Students Engaged in the Target Science Practices.

How often do your students do each of the following in your science class? Part A	Never in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times a week in the past 30 days)	Daily (four or five times a week in the past 30 days)
1. Generate questions or predictions to explore		M		F	
2. Identify questions from observations of phenomena			M	F	
3. Choose variables to investigate (such as in a lab setting)			M	F	
4. Make and record observations				M F	
5. Gather quantitative or qualitative data			M	F	
6. Organize data into charts or graphs				M F	
7. Analyze relationships using charts or graphs		M		F	
8. Analyze results using basic calculations			M	F	
9. Write about what was observed and why it happened			M	F	
10. Present procedures, data and conclusions to the class (either informally or in formal presentations)			M F		
11. Read from science textbooks or other handouts in class				M F	
12. Critically synthesize information from different sources (i.e., text or media)		M	F		
13. Create a physical model of a scientific phenomenon (like creating a representation of the solar system)		M F			
14. Use models to predict outcomes				M F	
15. Explain the reasoning behind an idea				M F	
16. Respectfully critique each other's reasoning		M	F		
17. Supply evidence to support a claim or explanation				M F	
18. Consider alternative explanations			M	F	
19. Make an argument that supports or refutes a claim		M	F		

Note. M = midpoint survey (Week 4) and F = final survey (Week 9).

At Week 4, Gwen rated herself as sometimes engaging in eight of the 10 target practices and as often or rarely engaging in the others (see Table 18).

Table 18: Gwen's Self-Report of the Frequency With Which She Engaged in the Target Science Practices.

How often do you do each of the following in your science instruction?	Never in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times a week in the past 30 days)	Daily (four or five times a week in the past 30 days)
1. Provide direct instruction to explain a science concept			**M**	**F**	
2. Demonstrate an experiment and have students watch			**M**	**F**	
3. Use activity sheets to reinforce skills or content			**M**	**F**	
4. Go over science vocabulary			**M**	**F**	
5. Apply science concepts to explain natural events or real-world situations			**M**	**F**	
6. Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)			**M**	**F**	
7. Discuss students' prior knowledge or experience related to the science topic or concept			**M**	**F**	
8. Use open-ended questions to stimulate whole class discussions (most students participate)			**M**	**F**	
9. Have students work with each other in small groups				**M**	**F**
10. Encourage students to explain concepts to one another		**M**	**F**		

Note. M = midpoint survey (Week 4) and F = final survey (Week 9).

Unlike the ratings she gave her students at Week 9, which showed no increase in frequency for more than half of the target items, Gwen rated herself as more frequently engaging in all 10 practices. It is important to note that at Week 9, Gwen rated herself as sometimes engaging in Item 10, to encourage students to explain concepts to one another on a daily basis.

4.3.4 Gwen's Midpoint and Final Interview Results

As in the previous sections, interview evidence of the factors that facilitated or inhibited the teacher's transition to learner-centered instruction is presented.

4.3.4.1 Facilitating Factors

At her midpoint interview, Gwen said that being able to revise or adapt existing resources facilitated her transition to a more learner-centered classroom:

> Well, I'm in-between, I use information from textbooks, but I create my stuff, incorporating phenomena pieces. I kind of revamp everything.

In addition, she recognized the importance of using phenomena that students could relate to their everyday lives:

> I think I've structured the right way because it might be a little bit different for students in certain classes because they're not used to a certain way of either having questions asked or answered. But I do pose a lot of open-ended questions to my students, especially since everything with Earth science is so real-world and relatable. I think it might be easier for my students to be able to answer certain questions just because it's a little more relatable to them.

Gwen also said it was useful to implement a point system to encourage her students to discuss through argumentation of evidence, which was a difficult skill for them to adopt.

At her final interview, Gwen continued to believe that being able to revise preexisting resources was necessary to facilitate the transition to a learner-centered classroom but also discussed the need to break the NGSS teaching practices into smaller steps:

> I'm just starting to implement slowly than what I have done in the past to incorporate more of the NGSS standards. I've been gradually going from teacher centered to learner centered, but this layout [the PD offered through this study] of the NGSS has given me more of an idea, a path to follow on how to become more learner centered and to be successful at it in smaller steps. It's so easy to take something that you've done for so many years and go through it and then tweak a few questions here and there. It doesn't

> have to be the entire lesson from the beginning. Small steps, tweak things here and there, change words around, change questions around, use resources. That will be able to get the kids thinking, even if it's a short video clip where you leave the sound off.

Gwen's class was diverse, with students at different levels, and she explained how she was able to move beyond simple questions by adapting the DOK tool:

> Well, the DOK wheel definitely helped me to scaffold, introducing topics with Level-1 questions, and then as I was digging deeper into the topic, moving from a Level 2 to a Level 3, sometimes to a Level 4. So my questions would always start with a Level 1, and by the end, they would have to be at least a Level 3. A few of them, I was able to get to a Level 4, especially with the analyzing and proving part because that's where the evidence base comes into. But as long as I'm able to push their level of thinking to at least a Level 3, I felt successful because they were always so stuck on Level 1 prior to that.

At Week 9, Gwen had more specific ideas about what facilitated her transition to creating a more learner-centered classroom. For example, she said having the students seated in a way that facilitated their collaborative work was helpful as evidenced by the following quotation:

> Definitely my seating arrangements could have been better. Seeing that the smaller group settings would work so much better if they're working with two other people or another person in a group, they would bounce more ideas off each other.

She also said that expecting students to look up and think through more information instead of just giving them the answers supported the changes she was trying to implement:

> It was a transition for myself because I analyzed what I had been teaching the previous year, and how I can tweak every lesson to make it more open-ended, argumentative, and having the students do more of the work and the figuring out piece than I had in the past. So, where the students were maybe answering more basic questions the year prior to, I would reword the questions and maybe not give them as much information on the concept and give them a more open-ended question where they would have to discuss between each other to try and solve an answer.

Gwen also discussed how her personal beliefs facilitated her transition as a science teacher:

> It was really myself. My willingness to want to. I think that's what's really holding back a lot of people in the science departments. They'll want to actually change and implement it."

4.3.4.2 Inhibiting Factors

At her midpoint interview, Gwen expressed how the complexity of the target practices was an inhibiting factor for teachers like herself who had no formal experience with the NGSS. She described needing the practices broken down into manageable steps:

> As of right now, I'm still learning a lot of the aspects of it and how to kind of break it down into some more simplistic ways of implementing.

As a result, it was not surprising that she felt the need for more engaging PD:

> Where we are taking our stuff, our materials that we currently have, and we can transform them, instead of just listening to someone tell us what it is and how it needs to be changed.

She also addressed the difficulty in getting her students to engage in evidence-supported argumentation, which she described as "a struggle." She added, "The students are just not participating." While students were used to being asked questions, they now had to argue among each other and provide evidence to support their reasoning, which they had to learn how to do. Gwen also identified lack of departmental support as another inhibiting factor and said she missed "having a staff that's willing also to change a little bit and adhere to it." Gwen believed that most veteran teachers were afraid of change:

> They're stuck in their ways as far as what they've been doing for the past X amount of years that they don't want to implement something that they might be scared of doing or the unknown.

At her final interview, Gwen emphasized how having to share her classroom space with other teachers inhibited her transition to a learner-centered classroom:

> For myself, the main thing that hindered me was having multiple teachers in the classroom. So, I couldn't rearrange the classroom as I fully wanted it because it wasn't uniform to what everyone needed. . . . That was the trickiest part. There were two other teachers in the class I was teaching in. So, I didn't have the accessibility to change from groups to rows, to groups to rows. But now that I have my classroom pretty much more to myself for the upcoming year, then I'll be able to keep it in groups.

Gwen explained how having the students' desks in rows all the time was not conducive for class and small-group discussions. She also discussed how easy it was to revert to her old teacher-centered habits and how this affected the students:

> It's always easier to go back and fall back to the teacher-centered because that's what everyone pretty much started with and what everyone knows. So, the transition is a bit of a struggle if the teacher is so teacher-centered because the students are going to be so used to the basic teacher talking, take notes, move on to the next thing. But once they're exposed to the open questions and thinking and then writing and then sharing it, they slowly get used to it.

Gwen also pointed out how the end-of-year standardized exams conflicted with the target science practices for students:

> It doesn't give the students the ability to give their answers the same way that we would in my class. So, the way that the discussion-based scenarios went and the argumentation, on the Regents it's pretty much right or wrong. That's it. There's no room for error. It's either one point or zero points.

She worried that preparing for the Regents examinations put the students back into the right or wrong mindset that was characteristic of traditional student learning and could set back their progress toward learner-centered instruction.

At Week 4, Gwen identified the need to revise and revamp materials as a major inhibiting factor, and this was still true for her at Week 9:

> I think trying to figure out what would be, either the best question or the best visual that would stump the kids. Because I didn't want something too basic where they would have enough prior knowledge that they would know what's going on. I wanted to try and find something that they knew slightly about, but not enough to just get the answer right away.

Finally, even after 9 weeks, Gwen continued to be concerned about losing control over her classroom and worried this might hold her back from more fully implementing the target practices: "I think everyone's afraid to get dirty, the classroom to get messy. And if teacher-centered, it's pretty straightforward."

4.3.5 Carol's Frequency Results

Carol's survey data are presented in Tables 19 and 20. At Week 4, Carol indicated that her students were engaging in all of the target science practices but not on a daily basis (see Table 19). Carol rated her students as rarely engaging in five of the target practices, sometimes engaging in eight of the practices, and often engaging in six of the practices. Interestingly, Gwen had similar ratings at the 9-week point. At the 9-week point, Carol rated her students as more frequently engaging in nine of the 19 target science practices.

Table 19: Carol's Report of the Frequency With Which Her Students Engaged in the Target Science Practices.

How often do your students do each of the following in your science class?	**Never (in the past 30 days**	**Rarely (once in the past 30 days)**	**Sometimes (once or twice per week in the past 30 days)**	**Often (three times per week in the past 30 days)**	**Daily (four or five times per week in the past 30 days)**
1. Generate questions or predictions to explore		M		F	
2. Identify questions from observations of phenomena			M	F	
3. Choose variables to investigate (such as in a lab setting)			M	F	
4. Make and record observations				M F	
5. Gather quantitative or qualitative data			M	F	
6. Organize data into charts or graphs				MF	
7. Analyze relationships using charts or graphs		M	F		
8. Analyze results using basic calculations			M	F	
9. Write about what was observed and why it happened			M	F	
10. Present procedures, data and conclusions to the class (either informally or in formal presentations)			M F		
11. Read from science textbook or other handouts in class				M F	

(continued).

How often do your students do each of the following in your science class?	Never (in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times per week in the past 30 days)	Daily (four or five times per week in the past 30 days)
12. Critically synthesize information from different sources (i.e., text or media)		M	F		
13. Create a physical model of a scientific phenomenon (like creating a representation of the solar system)		M F			
14. Use models to predict outcomes			M F		
15. Explain the reasoning behind an idea				M F	
16. Respectfully critique each other's reasoning			M F		
17. Supply evidence to support a claim or explanation				M F	
18. Consider alternative explanations				M F	
19. Make an argument that supports or refutes a claim		M	F		

Note. M = midpoint survey (Week 4) and F = final survey (Week 9).

She rated her students as engaging in 10 of the target practices at the same frequency as at the midpoint of the observation period. Notably, the greatest increase in frequency was for Item 1 (generate questions or predictions to explore).

Table 20 shows how frequently Carol rated her engagement in the target science teaching practices.

Table 20: Carol's Self-Report of the Frequency With Which She Engaged in the Target Science Practices.

How often do you do each of the following in your science instruction?	Never (in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times per week in the past 30 days)	Daily (four or five times per week in the past 30 days)
1. Provide direct instruction to explain a science concept				**M**	**F**
2. Demonstrate an experiment and have students watch		**M**	**F**		
3. Use activity sheets to reinforce skills or content			**M**	**F**	

(continued).

How often do you do each of the following in your science instruction?	Never (in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times per week in the past 30 days)	Daily (four or five times per week in the past 30 days)
4. Go over science vocabulary			**M**	**F**	
5. Apply science concepts to explain natural events or real-world situations			**M**	**F**	
6. Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)			**M**	**F**	
7. Discuss students' prior knowledge or experience related to the science topic or concept			**M**	**F**	
8. Use open-ended questions to stimulate whole class discussions (most students participate)			**M**	**F**	
9. Have students work with each other in small groups			**M**		**F**
10. Encourage students to explain concepts to one another			**M**		**F**

Note. M = midpoint survey (Week 4) and F = final survey (Week 9)

At the midpoint of the observation period, she rated herself as sometimes engaging in eight of the 10 target practices and often engaging in Item 1 (provide direct instruction). At the end of the observation period, she rated herself as engaging more frequently in all 10 practices. At Week 9, she said she was engaging in three of the item on a daily basis: Item 1 (provide direct instruction to explain a science concept), Item 9 (have students work with each other in small groups), and Item 10 (encourage students to explain concepts to one another).

4.3.6 Carol's Midpoint and Final Interview Results

4.3.6.1 Facilitating Factors

Carol noted at Week 4 that she accepted her role of being more of a guide and that this helped her transition to a more learner-centered classroom. She described trying to motivate her students to think about possible answers:

> I'm trying to pass the baton to them. So, I present a situation, and I want them to tell me why, when, or what things we can observe or measure. Now it's more on them. And it's been a slow process, but I believe, and I think the Regents results show that making this change can be an effective tool.

Carol also described how putting her students in groups facilitated learning:

> Sometimes, if you come into my class, maybe it looks like why are they talking so much. But at the end of the day, I think the fact that they are talking, they're collaborating, they're augmenting, and they are building up not just the relationship between themselves but also their self-confidence because they are talking to an equal.

She also identified the PD offered as part of this study as extremely helpful in her transition to a more learner-centered classroom:

> The professional development helped a lot and gave me the framework, telling me, okay, so this is the structure that we need to follow if we want to create an effective lesson if you want to make sure that we include the students as the center of the lesson.

At the end of the observation period, Carol again described how seeing herself as a guide facilitated her transition:

> I try to introduce more group work and give them more leeway to be more curious about the different topics we're discussing. So they had the chance to, for some topics, to do a little research on that particular topic.

Carol also shared how focusing on the type and level of questions she asked helped her shift her practices toward creating a more learner-centered classroom:

> Okay, I post a big idea question that's just thrown out there and have them [the students] discuss the possible answers to this question or maybe come up with new questions. Many times they're able to come up with an answer. If they don't answer, what we did in the past 10 weeks, we create a Parking Lot, which was one of the strategies that I learned during the PD. They write this question on a sticky note; we put it on this poster. And the question remains on the poster until the students come up with their own answer.

Consistent with her comments at Week 4, at Week 9 Carol was adamant about the continued need for PD to facilitate the transition to learner-centered instruction:

> [Being given] strategies that can help your students and yourself, to me, basically was privileged. . . . I think that is fantastic.

Similar to the other participants, Carol stressed how the arrangement of the students could facilitate implementation of the target practices, including *Engaging in argument from evidence* that was labeled as one of the more difficult skills for the students to acquire:

> They're sitting in groups, so you start this discussion, friendly discussion, and at the same time collaboration because they're going to come up each one with a part of the answer, maybe one student is stronger in this area. The other is stronger in a different area. But that argument will provide enough evidence, which triggers the argumentation.

Carol was the only participant to specifically identify how a learner-centered classroom allowed students to capitalize on all of their strengths in the pursuit of learning:

> In addition to teaching them how to learn, the science practices of the NGSS probably will give them the chance to use their own creativity, their own curiosity, at their own pace, reasonable own pace to be a collaborator. Also, to contribute to whatever their project is, although some are ESL students from impoverished [countries] and have weak academic backgrounds.

4.3.6.2 Inhibiting Factors

Given the diversity of students in Carol's classroom, at Week 4, she said that if she did not speak the same home language as her students, that would inhibit her transition to a more learner-centered classroom:

> So, that communication in their native language makes them more relaxed. Okay, I'm going to understand this teacher; that doesn't mean that they're going to all get As or 95% in the Regents, but at least they feel that they can probably make it because somebody speaks the same language. A common ground of connection, I say.

Carol also stressed how difficult it was for her to make connections to the engineering practices and how this interrupted her progress toward more student-centered teaching:

> We need to find ways to implement these engineering practices for them to create models or understand the engineering, for example, an artificial heart or kidney or whatever it is. That will take more time. And I'm just trying to juggle those things.

At Week 9, Carol identified her old habits and mindset as a major inhibiting factor:

> I thought my role was to provide all the information to the kids, basically digest the information to them. And that was a very heavy role because basically, I had to plan, I

have to communicate all the information, digest it for them, then help them go through the textbook and things like that.

After participating in this study, Carol said she understood the need to change her mindset and how she viewed her role as a teacher: “This is not what I’m going to do, but what the students are going to do, what they’re going to learn and what can they create, so I think that takes time.” She explained how, given the diverse backgrounds of her students, they needed more time to develop the foundational skills necessary to implement the target science practices:

> And the other thing is mostly my students, they come from communities in DR, in El Salvador, Guatemala, Honduras and many of these students due to their poor background, or maybe the lack of formal education in their countries, the leader that they bring is a very teacher-oriented or teacher-centered kind of lesson, and it’s very informal. I don’t think, at least in the rural areas of these countries, they don’t have that structure to learn.

Carol said these students were referred to as gap students due to the gap between their educational experiences in their country of origin and what was expected of them in U.S. schools.

4.3.7 Kate’s Frequency Results

Table 21 presents the frequency data reported by Kate regarding her students’ engagement in the target science practices. At the 4-week point, Kate rated her students as rarely engaging in 13 of the 19 target practices, sometimes engaging in three of the practices, and often engaging in three of the practices.

Table 21: Kate’s Report of the Frequency With Which Her Students Engaged in the Target Science Practices.

How often do your students do each of the following in your science class?	Never (in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times per week in the past 30 days)	Daily (four or five times per week in the past 30 days)
1.Generate questions or predictions to explore				M F	

(Continued).

How often do your students do each of the following in your science class?	Never (in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times per week in the past 30 days)	Daily (four or five times per week in the past 30 days)
2. Identify questions from observations of phenomena				MF	
3. Choose variables to investigate (such as in a lab setting)		M		F	
4.Make and record observations		M		F	
5. Gather quantitative or qualitative data			M	F	
6. Organize data into charts or graphs		M F			
7. Analyze relationships using charts or graphs			M	F	
8. Analyze results using basic calculations			M F		
9. Write about what was observed and why it happened		M F			
10.Present procedures, data and conclusions to the class (either informally or in formal presentations)		M	F		
11. Read from science textbook or other handouts in class				M F	
12. Critically synthesize information from different sources (i.e., text or media)		M	F		
13. Create a physical model of a scientific phenomenon (like creating a representation of the solar system)		M	F		
14. Use models to predict outcomes		M F			
15. Explain the reasoning behind an idea		M	F		
16. Respectfully critique each other's reasoning		M F			
17. Supply evidence to support a claim or explanation		M	F		
18. Consider alternative explanations		M	F		
19. Make an argument that supports or refutes a claim		M	F		

Note. M = midpoint survey (Week 4) and F = final survey (Week 9)

This echoed Ellen's ratings that also showed 14 target practices only occurring rarely at Week 4 but was more than double the number of items rated as rarely occurring at Week 4 for Gwen and Carol. At Week 9, Kate rated 12 of the 19 target practices as occurring more frequently. The greatest increase in frequency was for two items: Item 3 (choose variables to investigate) and 4 (make and record observations). For almost half (seven) of the target items, Kate reported no change in frequency from Week 4 to Week 9.

Table 22 presents Kate's frequency data for how often she believed she engaged in the target science practices.

Table 22: Kate's Self-Report of the Frequency With Which She Engaged in the Target Science Practices.

How often do you do each of the following in your science instruction?	Never (in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times per week in the past 30 days)	Daily (four or five times per week in the past 30 days)
1. Provide direct instruction to explain a science concept				M	F
2. Demonstrate an experiment and have students watch		M	F		
3. Use activity sheets to reinforce skills or content			M	F	
4. Go over science vocabulary		M			F
5. Apply science concepts to explain natural events or real-world situations		M	F		
6. Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)			M F		
7. Discuss students' prior knowledge or experience related to the science topic or concept		M		F	
8. Use open-ended questions to stimulate whole class discussions (most students participate)			M		F
9. Have students work with each other in small groups				M F	
10. Encourage students to explain concepts to one another	M	F			

Note. M = midpoint survey (Week 4) and F = final survey (Week 9).

At Week 4, she reported that she never engaged in one of the 19 target practices, rarely engaged in four of the practices, sometimes engaged in three of the practices, and often engaged in two of the practices.

Kate was the only participant to rate herself as never engaging in at least one of the target practices. At Week 9, Kate rated herself as engaging more frequently in all but two of the practices, which were rated at the same frequency as at Week 4. The greatest increase in frequency was for Item 4 (go over science vocabulary). At the end of the observation period, Kate rated herself as engaging daily in three of the 10 target practices.

4.3.8 Kate's Midpoint and Final Interview Results

4.3.8.1 Facilitating Factors

Kate said enthusiastically that she loved her job, " I do love being a science teacher." Kate believed loving what you do as a science teacher is the foundation to positive change. She also saw her role as that of a facilitator in the classroom. At Week 4, Kate said that what helped her transition to a more learner-centered classroom was seeing herself as a guide:

> Honestly, if it's done right, that's what I'll be, I'll be more like background noise. They [the students] will come forward and be the ones pushing themselves in their learning process. I'll just be there to kind of like guide them.

At the end of the observation period, Kate again emphasized how it helped to see herself as a guide:

> If the focus is going to be about students and not us, where students are now going to take on an active role in their learning, in the learning process, then I'm all in. . . . Believe it or not, students learn better when they learn from each other. They don't want to hear me all the time.

She added, "The NGSS, this is a perfect example, how they could design their own experiment without you doing it for them or walking them through it." Another facilitating factor that Kate identified at Week 9 was recognizing the following:

> Students are not empty vessels. They are coming to us with knowledge. They may have things that we have to tweak a little, misconceptions, but they're not empty, and we have to hear them more than hearing ourselves.

Like the other participants, Kate recognized that the students' seating arrangement could either help or hinder the transition process, and she described how she set up her classroom to facilitate class and small-group discussions. Finally, Kate discussed how the PD offered as part of this study helped her implement the target science practices to a greater degree:

> It has been years since I received the kind of professional development like the one for the teachers' transition research program.

4.3.8.2 Inhibiting Factors

At Week 4, one of the main issues Kate identified as inhibiting her transition was how reluctant the other science teachers were to try new approaches and the lack of support provided to teachers who were interested in doing things differently:

> I think if we as teachers, me, myself included, focus and decide that we're going to do this, we're going to really go hard and really use this, the NGSS, and not just try to wiggle out of it. I think we can improve education in the United States. But now we will really create engineers, people who can think without you having to tell them what to do.

According to Kate, "I'm telling you from what I've experienced here, a lot of teachers are negative, and they're not willing to try something new. That's the first thing–negativity." As a result, Kate said the shift to using the NGSS science practices required more administrative support to motivate science teachers. Interestingly, Kate was the only participant who mentioned students' attitudes and how a lack of student buy-in could be an inhibiting factor that discourages teachers.

Because many of Kate's students were multilingual learners who struggled with English, expressing complete and coherent responses and engaging in argument from evidence was often a difficult task for them. As a result, Kate said their limited English proficiency inhibited her and her class from becoming more learner centered:

> Because right now, what we do is I will scaffold for the students. If I ask them a question and I know that they're not going to be able to answer, it is too difficult, I'm going to help them by breaking it down and rebuilding it back for them. So, I'm going to break. . . . "Remember, I showed you a question, and you said, 'No, stop right here and make that one question and to make that. . . ." You broke up the one question into three parts. That's how I do it.

As much as her ELL students struggled, they did try. However, for some of them, the language was just not there–the foundation was missing–and this was a major inhibiting factor:

> I've met students who have told me that they didn't go to school or missed several grades or maybe school was not on their list as the priority.

Kate recognized that transitioning to a more learner-centered classroom was going to take time and effort on her part, but she worried that not all teachers would be willing to put in the effort needed: "Yes, it's going to be hard for me. Yes, it's going to take time. Yes, I'm probably going to have to spend my summer, but it is what it is." In addition, Kate echoed what the other participants said about the perception of losing control in a learner-centered classroom and discussed how fear of losing control could be another inhibiting factor:

> There's going to be a challenge because now you've been teaching for so many years like me. This is what my 17th year and I taught, I know how I teach, and I know how I am in my classroom. Now, I'm going to have to relinquish all that. Give up my power.

4.3.8 Summary of Question 3

The SIPS illuminated how often the participants believed they and their students were engaging in the target science practices during the research period. For the most part, the participants believed implementation of the practices increased over the course of the study. The interviews with the participants helped explain why some practices were harder than others to implement and provided the participants with an opportunity to delineate what they would need to more fully and frequently implement the target science practices. Most notably, all of the participants said they needed more support, including support from fellow science teachers, support from administrators, and additional PD opportunities. In addition, the participants said they needed more time to prepare for implementing changes in their instructional practices and classroom setup and would like to have the time to make the necessary changes in a stepwise manner. Overall, all of the participants saw the benefits of learner-centered instruction and said they were committed to continuing the changes they initiated through their participation in this study.

Chapter 5: Discussion, Implications, and Conclusions

The focus of this study was to document and analyze how a sample of high school science teachers adapted and utilized new approaches in science teaching after a PD workshop using the science practices of the NGSS. This research is timely because more than 44 states in the country have already adopted or adapted the NGSS and are in various stages of implementation. NY, where this study took place, is currently transitioning toward fully implementing its new science standards (NYSSLS) based on the NGSS (NYS Education Department, n.d.). Since the NGSS require a significant shift in teaching to implement the NGSS standards and philosophy, this study's findings may inform future PD efforts and help science teachers make the changes necessary to meet the new standards.

My study examined how the participants used the NGSS science practices of *Asking questions* and *Engaging in Argument from evidence* as they implemented learner-centered instruction in their classrooms. The SEPs underscore student participation and de-emphasize lower-order content. A learner-centered environment is central to the NGSS. In this study, Webb's DOK rubric, adapted from Hess (2013), was used to examine the participants' level of questioning. Here, the questioning levels were used as evidence to characterize each teacher's transition toward a learner-centered classroom. After the teachers participated in an all-day, 8-hour Saturday PD workshop, they were observed weekly teaching the same science class for 9 weeks. The workshop served as a context for this study by providing information on the NGSS and student-centered learning. Hence, the teachers had a basic understanding of these professional practices to incorporate them into their subsequent lesson planning and classroom practices. The DOK rubric was used to record evidence of teacher practice.

At the midpoint of the observation period (Week 4) and after the final observation (Week 9), the participants completed one-on-one interviews and the SIPS regarding their science practices and experiences toward transitioning to more learner-centered instruction.

The purpose of this study was to document and analyze evidence of the teachers' transition from teacher-centered to learner-centered classrooms. A mixed-method research design was employed for this study. Classroom observations, surveys, and individual interviews were the main forms of data collection. The research questions will be discussed in sequential order and include a comparative analysis where appropriate, including relevant citations to published findings.

5.1 Research Question 1

What are the characteristics of teachers' transition from a traditional teacher-centered to a learner-centered approach following a professional development workshop with a focus on *Asking questions* and *Engaging in argument from evidence* from the phenomenological approach of the NGSS?

This study analyzed data using classroom observation learner-centered rubrics, observation notes, surveys, and transcripts of audiotapes from classroom observations and interviews to answer this question. The results are shown in Figures 1 through 5 and Tables 1 through 4 in Chapter 4. The classroom rubric adapted from Hess (2013) depicts the critical evidence that indicates to what extent a teacher uses a learner-centered instructional approach. There are five primary sources of evidence in the learner-centered rubric: (a) the role of the teacher, (b) the balance of power, (c) the function of content, (d) the student responsibility, and (e) the learning potential in assessments.

The overall results (i.e., the combined frequency of all teacher participants; see Table 4), exhibited shifts toward learner-centered instruction over the 9 weeks of observation. As shown in Table 2 of Chapter IV, the teacher-centered category had the lowest average frequency counts, and the learner-centered category had the second-highest overall score. This finding is noteworthy because prior research has shown that teachers generally resist instructional reform in science education (Cuban, 2013) unless it is consistent with their current beliefs. Teachers' beliefs are instrumental in reforming science education (Reiser, 2013). The fact that the participants in this study were all volunteers may mean that they entered the study already interested in making changes in their professional practices.

The Earth science teacher participants (Ellen and Gwen) had higher transitional scores than the living environment teachers (Carol and Kate). Of the lessons observed, the highest transitional frequency counts were for Ellen's Observation 7, with Kate's being the least. Observation 2 was Gwen's highest transitional value, whereas Carol's best observed transitional practice was in Lesso 3. Kate's transitional counts were best during Observations 7 and 9. The Chi-square analysis of the participants showed consistency in their transitional classroom practices, and this was probably not due to chance, albeit the sample size was small. The differences in the total frequencies indicate that the value for the transitional category (390) (Mean = 97.5, SD = 13.3, $p < 0.01$) was significantly larger than the frequencies for the other two categories of learner centered and teacher centered. Given the emphasis placed in the PD on encouraging the participating teachers to move more deliberately toward a transitional status in their teaching, on the way to fully learner-centered instruction, this result shows a consistent pattern of transitional practices among the four teachers. This is consistent with what would be expected because the participants acknowledged that they were initially teacher-centered.

According to McComb (1997), teachers who were willing to change their beliefs and practices experienced higher effectiveness in the classroom.

Three of the participants' most highly rated learner-centered lessons occurred on or before Lesson 7. The exception was Carol whose highest learner-centered lesson was Observation 9, and the other teachers became more teacher centered as they approached Observation 9. It is important to note that this study was conducted from mid-march to May, ending 2 weeks before the annual NYS science Regents examination in June of 2019. Teachers were quite concerned in the end about their coverage of content for the Regents examination. For example, the highest transitional teacher, Ellen, a dedicated participant, said in her final interview, "So, I feel like I was worried more for the Regents and having them ready . . . in the end." I observed that having the Regent's examination (a content-driven test) at the end of the year did not accommodate the participants' learner-centered approach. And according to Hayes et al. (2019), in some contexts, teachers feel overwhelming pressure from testing. Here, my findings contribute to the dialogue on transitional shifts and the complexities of the external factors that influence teachers' experiences and practices. As noted by other researchers, it is challenging to align reform with external requirements, such as standardized tests, and teachers' beliefs that create the space within which teachers do the work (Darling-Hammond & Richardson 2009). In this study, I compared the findings for Research Question 1 with the highest teacher-centered and learner-centered tallies and Lesson 1 data to better characterize the participants' transitions.

5.2 Research Question 2

What characterizes teachers' professional practice during their transition from a traditional teacher-centered to a learner-centered approach with respect to the phenomenological approach of the science and engineering practices of *Asking questions* and *Engaging in argument from evidence?*

The NGSS science practices of *Asking questions* and *Engaging in argument from evidence* reflect scientists' and engineers' skills in their professional work. In addition, NGSS science lessons are anchored in real-world phenomena that promote student engagement and learning anchored in a phenomenon (Achieve Inc., 2022). Hess's (2006) adapted version of Norman Webb's DOK model of asking questions shows the alignment between NGSS standards and NGSS assessments (Nappi, 2017). Instead of the traditional presentation of lessons in consecutive order, the NGSS call for the focal phenomenon to drive the questions during a lesson (Reiser, 2013). This shift involves figuring out why or how something happens related to a relevant phenomenon (Achieve Inc., 2022).

5.2.1 Teachers' Use of Questioning

To answer Research Question 2 and to characterize the teachers' transition to a more learner-centered classroom, the frequency of the teachers' questions and the DOK coding of their questions (Level 1 to Level 4) was recorded and examined. According to Hess (2013), there are four DOK levels. Level 1 is the recall of information requiring a rote response. Level 2 is more than a single-step process and usually involves classifying or making observations. Level 3 involves strategic thinking and planning using evidence and requires students to explain their thought processes. Level 4 involves planning, complex reasoning, and designing an investigation with several variables (Hess, 2013). Observations of the participants' classroom teaching included the following: (a) observations of Ellen, Gwen, Carol, and Kate while they were teaching, (b) coded transcripts, and (c) a teacher and student rubric. Notes from my classroom observations were used when further clarification or reference was needed as I coded for the DOK levels of the participants' questions.

Ellen was an Earth science teacher for Grades 9 and 10. Ellen consistently asked questions every 5 minutes over the 9 weeks of observed lessons, except for Lesson 6 (see Table 5). Lesson 6 focused on the students developing their models as they planned and carried out their investigations to study the heat capacity of water and sand related to the ocean and beach. This lesson incorporated more of the other science practices that were not the focus of this study, which may explain why Ellen was observed asking fewer questions. It is important to note that both the *Framework* and the NGSS expect "students to be engaged in multiple practices throughout the course of instruction" (Pruitt, 2014) Out of a possible 72 tallies for consistent questioning, meaning at least one question was asked every 5 minutes of the 40-minute lesson observed each week for 9 weeks, Ellen obtained 62 tallies. The peak time for most questioning was between the 11th and 25th minute of the 40-minute class. Ellen asked the most questions during Observation 3 (the third week); her most highy rated learner-centered lesson revealed continuous questioning for the entire lesson. DOK Level 2, which requires skill and concept learning, and Level 3, which involves strategic thinking, showed substantial frequency counts in Observations 1 and 3, with Observation 3 being the most highly rated learner-centered lesson. However, there were fewer questions asked in Observation 4. There were also fewer questions for the most teacher-centered observation, especially higher-level questions. Historically, science education standards are often fixated on discrete facts, but the NGSS SEPs expect students to show deeper content understanding (Pruitt, 2014) and to answer more explanatory questions (Reiser, 2013).

Lesson 4 showed evidence of being teacher-led from both the learner-centered evidence in the coding rubric and the DOK levels of the questioning chart. It would be interesting if these two tools could serve as an essential guide for teachers interested in transitioning to a learner-centered classroom. *Engaging in argument from evidence* did not often occur in Ellen's nine observations. Only 14 tallies were for *Engaging in argument from evidence* compared to the cumulative 62 tallies observed for *Asking questions* over the 9 weeks. Drew and Thomas (2018), in their survey study of secondary science teachers' implementation of NGSS literacy practices, also observed that this SEP was the least implemented practice. Lessons 6 and 9 showed zero counts, whereas Lessons 5 and 1 had the highest count of three for this NGSS category.

Gwen was also an Earth science teacher who had taught for 7 years and was not tenured at the time of this study. Her class was general Earth science, with inclusion students having 504/IEPs. Observation 3 was the only lesson in which Gwen consistently asked questions every 5 minutes. Gwen's total tally for asking questions was 61 out of a possible 72; most of her questioning occurred after the first 15 minutes. Gwen's reference point lesson (Observation 1; see Appendix J) showed a total of 24 questions, 20 of which were Level-1 questions, three were Level 2, one was Level 3, and none were Level 4. However, during Observation 4, Gwen's highest learner-centered lesson, she asked a eight Level-2's questions, 10 Level-3 questions, and four Level-4 questions. She asked a total of 23 questions (see Appendix K). During this observation, the students were even asked to predict if it would rain in the next 5 hours based on the given data. Also, one of Gwen's Level-4 extended thinking questions asked the students to analyze the dew point and temperature for the past 5 hours. Gwen's highest teacher-centered class, Observation 7, had a combined total of 12 questions with no Level-4 extended thinking type of questions. And Observation 7 had the fewest intervals in which Gwen was observed asking questions (i.e., five).

The total tally for Gwen's class was 20 (see Table 8) for the SEP of *Engaging in argument from evidence*. Most of these incidents were only for two consecutive 5-minute intervals, except for Observations 4 and 6. Again, Observation 4 was the highest learner-centered lesson; hence, there may have been a correlation between asking questions and the amount of argumentation that was experienced in this lesson.

Carol was a tenured living environment teacher with 10 years of experience. She was also a bilingual and an English as a New Language (ENL) teacher. Carol's overall tally of *Asking questions* was 56, but Carol had three lessons in which there was consistent questioning for every 5-minute interval: Lessons 2, 3, and 6. Her highest teacher-centered lesson, Observation 7, only had four intervals in which she asked questions. However, during classroom observations, evidence of peak questioning was observed between the first, second, fourth, and fifth intervals. The DOK questioning levels for Observation 7 had six Level-3 questions, one Level-2 question, four Level-1 questions, and no Level-4 questions (see Appendix O).

Despite being solidly learner-centered, Lesson 9 did not show questioning during the last interval of the 40-minute lesson, resulting in a total of seven tallies instead of eight. On the contrary, her highest learner-centered lesson, Observation 9, had four Level-4 extended thinking questions, four Level-3 strategic thinking questions, two Level-2 questions, and eight Level-1 recall types of questions (see Appendix N). Here, it was observed that the level of questioning might facilitate a transition to a more learner-centered classroom. Interestingly, there was no student *Engaging* in *argument from evidence* for the entire lesson, a tally of zero, but this did not interfere with this lesson being highly learner centered.

5.2.2 Teachers *Asking Questions* and Students *Engaging in Argument From Evidence*

Table 10 shows the tally for Carol's students *Engaging in argument from evidence*. During the 9 weeks of observed lessons, her students demonstrated *Engaging in argument from evidence* during 19 of the 72 intervals. *Engaging in argument from evidence* seems to be a challenging SEP. This is another case in which the teacher's implementation of *Asking question*s far outnumbered her students instances of *Engaging in argument from evidence*. As shown in Table 10, Lessons 1, 2, 4, 6, and 9 had no tallies for argumentation. As Kang et al. (2019) reported, elementary school teachers also seem to struggle with implementing the practice of *Engaging in argument from evidence.* However, even though there was a lack of evidence of examples of *Engaging in argumentat from evidence*, these classes for Carol were not characterized as teacher-centered, due to the presence of other positive attributes. On the other hand, there was a consistent indication of *Engaging in argument from evidence* for Lessons 3 and 8 for all 5-minute intervals, except the first interval of Lesson 3. Based on the observations, the practice of *Engaging in argument from evidence* seemed to be more easily implemented when it was the sole element in the design of the lesson and not integrated with the other science practices.

At the time of this research, Kate was a tenured living environment bilingual teacher with 18 years of experience. Like the other participants, she was fully willing to participate in the PD, learn the science practices, and incorporate them into her lesson plans. Of the nine lessons observed, only three did not have the maximum tally of eight for *Asking questions*. Those were Lessons 2, 6, and 9. Lesson 6, Kate's highest learner-centered lesson, had a tally of 6, and

Lesson 9, her highest teacher-centered lesson, had a tally of 4. Her total was 65 out of a possible 72. Kate's tally of 65 for *Asking questions* was the highest of all the participants (see Table 11). Although Ellen showed the highest transitional scores according to the rubric, Kate had the highest learner-centered score (Table 3).

In terms of *Engaging in argument from evidence*, Kate's class tally was 20, a tie for highest with Gwen. There may have been a correlation between her learner-centered lessons and her high-frequency tallies for *Asking questions* and *Engaging in argument from evidence*. These NGSS science practices are intended to improve students' PEs (NRC, 2012). Kate had many Level-1 questions, 30 in total (see Table 13), but far fewer Level-2 and Lvel-3 questions. According to Hess et al. (2009), applying Webb's DOK levels to teachers' questions could provide important feedback to teachers and serve a fundamental role in helping teachers shift toward more learner-centered practices during science education reform.

Ellen showed strong transition evidence as her lessons were observed to have the highest transitional score and the greatest number of questions asked (seeTable 14). It is important to note that Kate's students were English Language Learners. Often, her questions came across as too complex, and she would reword, simplify, and repeat them to facilitate her students' comprehension. Still, the content remained challenging, as shown in Appendix Q. There was no evidence of Level-4 questions for the three main lessons examined for Kate: Lessons 1, 6, and 0. Overall, from my classroom observations and field notes, the SEP of *asking questions*, especially Level-2 and Level-3 questions, evoked learner-centered moments within the participants' classrooms. For professional discourse among scientists, questioning is a central feature to gain deeper understanding (Harris et al., 2012). It plays a significant role in creating a learner-centered classroom and helping students achieve the goals of the NGSS, including developing a greater proficiency in *Engaging in argument from evidence*.

5.3 Research Question 3

This section addresses Research Question 3: What factors do teachers identify as facilitating or inhibiting their ability to transition from a traditional teacher-centered to a learner-centered approach with respect to *Asking questions* and *Engaging in argument from evidence* from the phenomenological approach of engaging in the science and engineering practices?

The teachers in this study varied in terms of their professional backgrounds. For example, Ellen and Gwen, both Earth science teachers, were not tenured at the time of this study, but Carol and Kate, both living environment teachers, were tenured with more than 10 years of teaching experience each. Despite these differences, some thought-provoking commonalities were found among the four teachers. Below, I discuss the findings for Research Question 3.

5.3.1 Facilitating Factors

The main facilitating factor reported by the teachers was support. It was the first area identified by all of the participants as useful. It is important to note that the PD was seen as a critical form of support by both the newer teachers and the veteran teachers. Most surprising and disturbing was the report by Ellen and Gwen, the newer teachers, who both stated that the PD workshop was their first formal exposure to the NGSS. If teacher preparation programs are not sufficiently preparing teachers to implement contemporary standards, and schools and school districts are not mandating (or even offering) teachers PD opportunities that address how to implement the new standards, who can teachers turn to for support as they struggle with the challenges inherent in transitioning to learner-centered instruction? As such, it is not surprising that all of the teachers echoed the perception that they were on their own in trying to figure out how to successfully maneuver their transition toward student-centered learning. Moreover, they called for more support (tangible and intangible) from colleagues and administrators.

Although the teachers implemented the target practices to different degrees during the 9 weeks of this study, they all described the PD workshop as helping them understand the new standards and break the target practices into manageable steps. Obviously, just reading about the NGSS is not enough to foster implementation, and the teachers in this study said they needed PD that offered hands-on experiences, resources, and on-going support to make lasting changes in their classrooms. This is supported by current research on effective PD that points to the need to move away from "one-shot wonders" (Ferlazzo, 2018, p. 8), which permeate the field. This also points to the need for PD experiences that focus more on concrete steps teachers can immediately take and build upon, rather than general overviews that fail to consider real-world classroom constraints.

The participants also discussed how the PD workshop motivated them to further their transition efforts. The need for colleagues and administrators to support teacher change was identified by three of the participants as a facilitating factor and speaks to the fact that school reform requires a systems approach. In other words, teachers cannot be successful in isolation and require colleague, administrator, and district support. This was particularly evident toward the end of the study when multiple teachers expressed concern about having to revert to their traditional classroom practices to prepare their students for the Regents examinations because these tests still required students to engage in the type of thinking and responding that was typical of traditional teaching and learning. Clearly, there is a disconnect between what is called for by the new state science standards and what is being asked of teachers and students by the state education department. Such incompatibilities leave teachers confused and frustrated, as evident from the participants' final interviews. Again, teachers do not work in isolation, and the responsibility for implementation of the new standards cannot rest solely on their shoulders; there must be collaboration, communication, and contributions between teachers, departments, schools, districts, and the state.

It is interesting to note that the facilitating factors identified by the participants at Week 4 continued to be facilitating factors at Week 9; however, the participants identified twice as many inhibiting factors at Week 9 than at Week 4. This points to the significant time it takes to fully implement large-scale reform and to measure its effects. In the beginning, teachers may be motivated and enthusiastic about implementing reform efforts, and it may take time before they encounter new serious barriers or other problematic issues that could be ameliorated by further support and PD experiences.

5.3.2 Inhibiting Factors

At the end of this study, the main inhibiting factors identified by the participants (beyond lack of support) were limited physical classroom space, challenges inherent in *Engaging in argument from evidence*, and insufficient time to innovate and properly engage students with the new NGSS practices. For example, both Earth science teachers, Ellen and Gwen, lacked a dedicated classroom space. As a result, they described how moving from room to room was a major challenge that impeded their ability to set up an interactive learner-centered space before each class began. Because not all teachers at the school were on board with the new standards, when Ellen and Gwen entered a classroom, it was usually set up in the traditional format of having students' chairs in rows, and there wasn't time to rearrange all of the students' chairs.

However, having the chairs in rows impeded partner and other small-group discussions and collaborative work, which is promoted by the NGSS SEPs.

Another inhibiting factor was the difficulty associated with the target practice of *Engaging in argument from evidence*. Many of the students in Carol's, Ellen's, and Kate's classrooms were classified as English as a New Language (ENL) students and had limited English proficiency that the teachers said made this particular science practice especially challenging for them. However, even Gwen's students, who were more proficient in English, apparently found this particular target practice among the most difficult, as evidenced in Gwen's interviews and rubrics.

In addition to the students' language issues, the teachers said some students lacked formal education experiences, and many others were used to passively receiving information from their teacher, leaving all of these students unfamiliar and even uncomfortable with taking an active role in their classroom learning process. Gwen directly stated that her students were not participating in this practice and, in response, she implemented a point system to encourage student participation in arguing from evidence. Ellen also acknowledged her students' difficulty in arguing from evidence, describing it as the most challenging aspect of using the study's target NGSS science practices. The teacher surveys confirmed that this target practice was observed less frequently than the other practices for all of the teachers' students.

Finally, at Week 9, each of the participants said that they and their students didn't have enough time to fully implement the target practices. Several teachers commented on needing more time to create lesson plans and that they could save time if they could learn to revise their current plans to meet the new standards. Time wasn't only an issue for the teachers. The participants said that students also needed more time to develop and engage in the target practices compared to the significant amount of time scientists require to develop scientific theories and explain them.

5.4 Conclusions

Learning by being told information is not the most effective means of developing the ability to construct and explain ideas and make informed decisions (NRC, 2012). This research study examined how teachers incorporated new approaches into their practice and endeavored to transition toward a learner-centered classroom after participating in a PD workshop on the SEPs of the NGSS. Overall, the teachers demonstrated increases in their transitional practices. During their interviews, the teachers shared their challenges in getting their students to *Engage in argument from evidence*. There was evidence that the teachers could more readily implement the SEP of *Asking questions* than get their students to demonstrate the SEP of *Engaging in argument from evidence*.

5.4.1 Limitations

This mixed-method study employed qualitative and quantitative analyses to analyze multiple data sources (rubrics, field notes, interviews, surveys). The goal was to explore how four teachers met the challenge of incorporating two of the SEPs from the NGSS into their classrooms practices and transitioned toward more learner-centered teaching practices. Within this scope, four teachers were purposefully sampled to permit an in-depth analysis through the research design, largely a case study approach. Studies of this kind generate insights into educational phenomena, which gain generality through potentiating further explorations in the same area of inquiry. Moreover, the varied sources of evidence, among even a small set of teachers, as explored here, can provide some heuristic generalizations about how teachers are challenged by new standards, particularly when existing institutional policies, structures, and demands are not fully consistent with the newer approaches. Clearly,to fully assess the generality of some of the findings, additional research with a larger sample of teachers from a variety of school settings and different social contexts is needed.

In this research, I assumed that the participants answered the interviews, surveys, and reflections honestly and truthfully, and the participants were also continually assured that their identities would remain confidential. They were assured that school stakeholders could not identify them. Thus, I felt assured that the teachers would not feel intimidated and could share their candid perceptions about the positive and negative aspects of meeting the challenges posed by the transition to newer methods of classroom practice.

5.4.2 Recommendation for Future Research

Based on the foregoing discussion, additional studies should be conducted to understand better how to improve opportunities for teachers to develop their SEPs based on the NGSS and bolster the emerging best evidence for how to transform science education experiences to better educate the wide range of students that teachers are increasingly asked to serve. There should be sufficient resources allocated for teachers to receive continuous professional support throughout their participation in research and work in classrooms to build their confidence and deepen their understanding of how to better transition to a learner-centered classroom.

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Appendix A

Learner-Centered Rubric for Classroom Observations (based on Weimer, 2013)

#1: The role of the teacher (The teacher is not a conveyor of information; the teacher is a facilitator. It's the students who do the hard messy work of learning; they are not passive recipients of knowledge.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: For the majority of the class session, the teacher does not simply convey information; the teacher facilitates significant learning experiences in which the students engage in the authentic work of the discipline and learn the information for themselves.	*Description: There is a mix of lecture and student engagement.*	*Description: The teacher does the vast majority of talking, summarizing, and analyzing.*	
1. For the majority of the class session, the teacher acts as a resource person (giving constructive feedback, eliciting different approaches, encouraging repeated attempts, etc.), working to support and enhance student investigations.	1. Occasionally during the class session, the teacher acts as a resource person, working to support and enhance student investigations.	1. The teacher does not act as a resource person during class, working to support and enhance student investigations.	
2. The teacher expects students to generate examples, review material, solve problems, lead discussions, critically analyze information, etc.	2. There are opportunities for the students to generate examples, review material, solve problems, etc., but these opportunities are limited or the purpose of the activities is not clearly connected to course material.	2. The class session consists predominantly of the teacher conveying information; students watch while the teacher works.	
3. Questions are welcomed by the teacher, and the teacher makes an effort to redirect to the rest of the class so that other students answer questions rather than the teacher.	3. Questions are welcomed by the teacher, but questions are mostly answered by the teacher rather than other students.	3. Questions from students may be entertained to a limited degree.	
4. The teacher ensures that the tasks students do in class are challenging.	4. The teacher ensures that the tasks students do in class are moderately challenging.	4. The teacher doesn't provide any opportunities for students to engage in challenging tasks. Alternately, the tasks that are provided are not very challenging.	

#2: The balance of power (The students have some control of the learning process.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: The students appear to have a great deal of control over the learning that occurs in the classroom.	*Description: The students appear to have some control over the class.*	*Description: The students appear to have no control over the class.*	
5. Student questions and comments often determine the focus and direction of learning/instruction.	5. Student questions and comments are encouraged and answered, but those questions/comments do not determine the focus and direction of the class or prompt the teacher to change the current focus.	5. Student questions and comments are rare.	
6. Students have control over what content will be learned.	6. Students appear to have some choices with regard to content, but not a great deal.	6. The teacher appears to control all aspects of the class session.	
7. There is a high proportion of student talk related to content, and a significant amount of it occurs between and among students.	7. There is a high proportion of student talk related to content but usually between teacher and student.	7. There is very little student talk related to content; the teacher does most or all of the talking.	

Learner-Centered Rubric for Classroom Observations (based on Weimer, 2013)

#3: The function of content (Instead of "covering" the material, the students develop learning skills and learn how to think like those in the discipline.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: The teacher does not overwhelm the students with a large amount of content. Content functions as a vehicle for skill development.	*Description: There is some evidence of the teacher and students addressing learning skills and using content to help students think like professionals in the discipline.*	*Description: Content is covered by the teacher and is not used in a way that promotes students thinking like professionals in the discipline. Learning skills are not developed by the students.*	
8. There is evidence that the teacher helps students learn how to ask good questions, how to read effectively, how to critically analyze information, how to write, how to study, how to summarize information, how to work effectively in groups.	8. There is some evidence that the teacher helps students learn how to ask good questions, how to read effectively, how to critically analyze information, how to write, how to study, how to summarize information, how to work effectively in groups.	8. There is no evidence that the teacher helps students learn how to ask good questions, how to read effectively, how to critically analyze information, how to write, how to study, how to summarize information, how to work effectively in groups.	
9. The tasks that students do in class seem to reinforce skill development (e.g., students need to read effectively in order to solve problems or analyze case studies in class; they need to work effectively in groups in order to be successful in the class).	9. Some of the tasks that students do in class reinforce skill development (e.g., students need to read effectively in order to solve problems or analyze case studies in class; they need to work effectively in groups in order to be successful in the class).	9. The students do no tasks in class that reinforce skill development; the teacher is primarily covering content.	
10. Content is utilized in such a way to provide opportunities for students to think like professionals in the discipline.	10. Content is utilized in such a way to provide some opportunity for students to think like professionals in the discipline.	10. Content is not utilized in such a way as to help students think like professionals in the discipline.	

#4: Student responsibility for learning (The teacher's role is to be approachable, caring, consistent, and make sure the student experiences consequences when he/she fails to live up to the responsibility.)

Learner-Centered	Transitional	Teacher-Centered	Comments
Description: The classroom atmosphere is such that students are held responsible for their learning and take that responsibility willingly.	*Description: The teacher does a relatively good job of ensuring that students are responsible for learning and that there exists a warm classroom climate, but the efforts fall short in some ways.*	*Description: There is little to no evidence that students take responsibility for learning.*	
11. Students are expected to have prepared before class and there is evidence that the majority in fact have actually prepared (e.g., they are able to answer questions about the prior information, they can apply the prior information to new situations, they ask questions that show that they've prepared beforehand).	11. Although students are expected to have prepared before class, many have not and there are no consequences.	11. There is little to no evidence that students were supposed to prepare anything for the class session.	
12. The teacher is patient and caring, knows all or most students by name. The teacher listens carefully to students. The teacher treats students fairly and consistently (in other words, no one gets "special treatment," there is consistency between what the teacher says and what he/she does).	12. The teacher is mostly caring, but there may be a few issues, such as some students getting special treatment, not knowing several students' names, occasionally seeming to not listen carefully to students, showing minor impatience occasionally. Alternately, the teacher appears patient and caring, but he or she interacts so little with students that it is difficult to evaluate other dimensions like the extent to which the teacher listens carefully, knows all of the students' names, etc.	12. The teacher does not exhibit patience or a caring attitude. The teacher appears to know very few or no students' names except for possibly a "favorite" or two.	
13. All or almost all students put effort into the class (e.g., they arrive on time, they're not on their computers or cell phones during the class, they participate in class when asked). If some students choose not to put in effort, the teacher is aware and takes action to engage them.	13. The majority of students put effort into the class (e.g., they arrive on time, they're not on their computers or cell phones during the class, they participate in class). However, when they fail to put effort in, there are no consequences (the teacher seems to not notice or ignores the behavior).	13. The majority of students are not paying attention or putting effort into the class (e.g., many students are late, they're on computers, etc.). The teacher does not seem to notice/care.	
14. Expectations are high, and students appear to respond positively. The students support each other in achieving those high expectations.	14. Expectations are neither high nor low. OR, expectations are high and some students respond positively whereas others appear to be frustrated and struggling.	14. Expectations are low. OR, expectations are high and students respond negatively.	
15. There is a positive climate in the classroom (e.g., mutual respect, good rapport between the students and the teacher and among the students, students listen to each other and respond to each other respectfully).	15. There is an average climate in the classroom. For example, the students are polite, but they don't seem to listen or respond to each other. Alternately, there is little opportunity to judge the climate because there is little interaction in the class.	15. There is a negative climate in the classroom. For example, students may be openly hostile to each other or the teacher. Students pay attention to the teacher but tune out when other students talk. Students "clockwatch" in the classroom.	

Adapted from "Learner-Centered Rubric for Self Assessment," by Northwesten Michigan College experiential learning institute, n.d. (https://www.nmc.edu/experiential-learning/files/learner-center-rubric.pdf

Appendix B

5-Minute Time Intervals for the SEPs

The rubric for the students' SEP	**1-5 mins**	**6-10 mins**	**11-15 mins**	**16-20 mins**	**21-25 mins**	**26-30 mins**	**31-35 mins**	**36-40 mins**
Asking questions (for science) and defining problems (for engineering)								
Developing and using models								
Planning and carrying out investigations								
Analyzing and interpreting data								
Using mathematical and computational thinking								
Constructing explanations (for science) and designing solutions (for engineering)								
Engaging in argument from evidence								
Obtaining, evaluating, and communicating information								

Note. This table was adapted from the eight practices in the NGSS SEPs to observe and measure the consistency in the practices in the participating classrooms.

Appendix C

NGSS SEPs of *Asking questions* and *Engaging in Argument From Evidence*

Asking Questions	Engaging in Argument From Evidence
• Ask questions that arise from careful observation of the phenomena, or unexpected results, to clarify andor seek additional observation. • Ask questions that arise from examining models or a theory to clarify or seek additional information and relationships. • Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. • Ask questions to clarify and refine a model, an explanation, or an engineering problem.	• Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, or ethical issues. • Evaluate claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of the argument.
• Evaluate a question to determine if it is testable and relevant. • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.	• Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
• Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of the design.	• Construct, use, and/or present an oral and written argument or counter arguments based on data and evidence.
• Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.	• Make and defend a claim based on evidence about the natural world or effectiveness of a design solution that reflects scientific knowledge and student generated evidence. • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Note. This table was adapted from the eight practices in the NGSS SEPs to observe and measure the consistency in the practices in the participating classrooms.

Appendix D

DOK Levels Chart

Table 1: Detailed Descriptors of Depth-of-Knowledge Levels for Science
(K. Hess, Center for Assessment, based on Webb, update 2005)

Level 1 **Recall & Reproduction**	Level 2 **Skills & Concepts**	Level 3 **Strategic Thinking**	Level 4 **Extended Thinking**
a. Recall or recognize a fact, term, definition, simple procedure (such as one step), or property b. Demonstrate a rote response c. Use a well-known formula d. Represent in words or diagrams a scientific concept or relationship e. Provide or recognize a standard scientific representation for simple phenomenon f. Perform a routine procedure, such as measuring length g. Perform a **simple** science process or a set procedure (like a recipe) h. Perform a clearly defined set of steps i. Identify, calculate, or measure **NOTE: If the knowledge necessary to answer an item automatically provides the answer, it is a Level 1.**	a. Specify and explain the relationship between facts, terms, properties, or variables b. Describe and explain examples and non-examples of science concepts c. Select a procedure according to specified criteria and perform it d. Formulate a routine problem given data and conditions e. Organize, represent, and compare data f. Make a decision as to how to approach the problem g. Classify, organize, or estimate h. Compare data i. Make observations j. Interpret information from a simple graph k. Collect and display data **NOTE: If the knowledge necessary to answer an item <u>does not</u> automatically provide the answer, then the item is at least a Level 2. Most actions imply more than one step.** **NOTE: Level 3 is complex and abstract. If more than one response is possible, it is at least a Level 3 and calls for use of reasoning, justification, evidence, as support for the response.**	a. Interpret information from a complex graph (such as determining features of the graph or aggregating data in the graph) b. Use reasoning, planning, and evidence c. Explain thinking (beyond a simple explanation or using only a word or two to respond) d. Justify a response e. Identify research questions and design investigations for a scientific problem f. Use concepts to solve non-routine problems/more than one possible answer g. Develop a scientific model for a complex situation h. Form conclusions from experimental or observational data i. Complete a multi-step problem that involves planning and reasoning j. Provide an explanation of a principle k. Justify a response when more than one answer is possible l. Cite evidence and develop a logical argument for concepts m. Conduct a designed investigation n. Research and explain a scientific concept o. Explain phenomena in terms of concepts	a. Select or devise approach among many alternatives to solve problem b. Based on provided data from a complex experiment that is novel to the student, deduct the fundamental relationship between several controlled variables. c. Conduct an investigation, from specifying a problem to designing and carrying out an experiment, to analyzing its data and forming conclusions d. Relate ideas *within* the content area or *among* content areas e. Develop generalizations of the results obtained and the strategies used and apply them to new problem situations **NOTE: Level 4 activities often require an extended period of time for carrying out multiple steps; however, time alone is not a distinguishing factor if skills and concepts are simply repetitive over time.**

This table was adapted from Hess, K. 2006

Appendix E

Midpoint and Final Survey Frequency Data Regarding Target Science Practices

How often do your students do each of the following in your science classes?	Never in the past 30 days	Rarely (once in the past 30 days)	Sometimes (once or twice per week in the past 30 days)	Often (three times a week in the past 30 days)	Daily (four or five times a week in the past 30 days)
1. Generate questions or predictions to explore					
2. Identify questions from observations of phenomena					
3. Choose variables to investigate (such as in a lab setting)					
4. Make and record observations					
5. Gather quantitative or qualitative data					
6. Organize data into charts or graphs					
7. Analyze relationships using charts or graphs					
8. Analyze results using basic calculations					
9. Write about what was observed and why it happened					
10. Present procedures, data and conclusions to the class (either informally or in formal presentations)					
11. Read from science textbook or other handouts in class					
12. Critically synthesize information from different sources (i.e., text or media)					
13. Create a physical model of a scientific phenomenon (like creating a representation of the solar system)					
14. Use models to predict outcomes					
15. Explain the reasoning behind an idea					
16. Respectfully critique each others' reasoning					
17. Supply evidence to support a claim or explanation					

18. Consider alternative explanations					
19. Make an argument that supports or refutes a claim					
How often do you do each of the following in your science instruction?	**Never in the past 30 days**	**Rarely (once in the past 30 days)**	**Sometimes (once or twice per week in the past 30 days)**	**Often (three times a week in the past 30 days)**	**Daily (four or five times a week in the past 30 days)**
1. Provide direct instruction to explain a science concepts					
2. Demonstrate an experiment and have students watch					
3. Use activity sheets to reinforce skills or content					
4. Go over science vocabulary					
5. Apply science concepts to explain natural events or real-world situations					
6. Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)					
7. Discuss students' prior knowledge or experience related to the science topic or concept					
8. Use open-ended questions to stimulate whole class discussions (most students participate)					
9. Have students work with each other in small groups					
10. Encourage students to explain concepts to one another					

Note. Adapted from "Understanding Teacher Instructional Change: The Case of Integrating NGSS and Stewardship in Professional Development," by K. N. Hayes, M. Wheaton, and D. Tucker, 2019, Environmental Education Research, 25(1), p. 160 (https://naaee.org/eepro/research/library/understanding-teacher-instructional), Copyright 2019 by the North American Association for Environmental Education.

Appendix F

Teachers's Interview at Mid and Final Survey

Interview protocol – individual semi-structured

Time of the interview:

Date:

Place:

Name of Interviewer:

Name of Participant:

Name of School District:

Introduction to the interview: This study aims to examine what characterizes the shift of a teacher-centered approach to a learner-centered approach using Next Generation Science Standards (NGSS) as a tool. Hopefully, this study will provide a better understanding of what it takes for teachers to shift towards learner-centered teaching with the support of science and engineering practices.

The teachers' classrooms were observed for their phenomenological methods of the science and engineering practices, their lesson plans, field notes were written, surveys taken, and an interview conducted. Then

1. How would you describe your experience as a science teacher?
2. How long have you been teaching?
3. How would you describe your role as a science teacher? The student's role and is your classroom diverse in population or learning levels?
4. What is your experience with the NGSS?
5. Describe a typical lesson in your classroom before the NGSS training.
6. And how is your classroom different now? What specific changes have you made due to the PD workshop in your classroom?
7. For the professional development with the emphasis of implementing a phenomenological item, and then we looked at two main components of asking the

questions and using argumentation, how would you describe that part of your lesson plan?

8. If not properly implemented, what would you say was the reason: lack of information, knowledge, time, more preparation from the PD?
9. Do you feel you had to make significant changes or a big transition from teacher-centered to the next generation science standards to learner-centered?
10. Would you say that the PD you attended was clear enough or give you enough guideline?
11. Well what would be some of the specific changes you've made in the classroom because of the implementation of the NGSS or PD?
12. How do you feel the students responded to the class where the science practices were implemented?
13. Do you feel the students had/were given opportunities ask questions?
14. Were the students allowed to engage in student-driven argumentation, whereby they supported their claims with evidence?
15. What are some of your areas of concern for implementing from the teacher to learner-centered using the phenomenological approach?
16. Do you believe the NGSS compliments the Regents state test at the end of the academic year or no?
17. For the time that you got closer to the Regents do you believe you reverted to a more teacher-centered approach?
18. Did your teaching approach or styled changed as you got closer to the preparations for the Regents exam at the end of the year?
19. What opportunities or supports have been available at your school to help you transition into the next generation of science standards?
20. Would you say your district has not yet been fully emerged in the next generation science standards?
21. So how prepared do you feel you were to implement the next generation science standards on a scale of one to ten, ten being very prepared and one being least?
22. What are your areas of concern for the NGSS science practices to be implemented so teachers can transition from a teacher-centered to a learner-centered approach?
23. How would you characterize the use and benefits of the adopted NGSS? What was useful? What would you say are some of the benefits of using the phenomenological approach?
24. What are some of the specific things you actually did as a phenomenological approach that were used for higher level questioning or for the arguments from evidence and you can say thanks to the PD I did that or because of the PD?
25. Do you think you could name specific methods that you have used as a teacher that helped with the implementation of the practices of science and engineering, mainly the asking of questions and argumentation from evidence?
26. What factors would you say facilitated the ability to make a transition to the learner-centered approach?

27. What factors hindered your transition as a teacher to the implementation into the learner-centered model in the classroom?
28. Would you say you received support in getting any hands-on material you needed?
29. How would you describe your questioning approach using your DOK the depth of knowledge questions from simple to critical thinking questions?
30. Do you have any ENL students in your class? What about their oral skills and reading skills?
31. Did you have any questions about the 9-week study approach during this entire process of me observing in your classroom? Do you think there was something different you would have liked to try, see or do differently?
32. So how do you believe teachers can transition from teacher-centered to learner-centered?
33. Is there anything you would like to add considering the effort you made and teachers will have to make to go from a teacher-centered to a learner-centered using the NGSS as a tool?
34. Do you have any other questions or thoughts for me?
35. Thank you so much.

Appendix G

Ellen's Observation 1 Reference Point

Level 1 12 **Recall and** **Reproduction**	L1 RR What else is different? L21 L1 RR The difference between the moon and the planets? L- L30 L1 RR What else is different? - L38 L1 RR what is Jovian made of ? -L48 L1 RR Define mean distance from the sun? -L69 L1 RR Define a revolution? -L76 L1 RR What is rotation? L84 L1 RR What is equatorial diameter? L88 L1 RR Recall the information from yesterday, about how many times more it is Denser? L102 L1 RR What is a day for us?- L187 L1 RR what does revolution means? – L211 L1 RR what does revolution means? L218
Level 2 9 **Skill and** **Concept**	L2SC Tell me "from the smallest to the biggest planet"? -L133 L2 SC Classify, which planet is closest to the sun?-L149 L2 SC What are your observations based on the reference tables? L164 L2 SC make observations compare and tell of the difference between Venus and Earth? -L183 L2 SC interpret what the reference table means by rotation? -L190 L2 SC compare the revolution of the planet and rotation, which is the fastest? L 199 L2 SC infer and classify what can be said of Saturn and Jupiter? -L205 L2 SC Interpret from observations how fast is the rotation of Earth? L231 L2 SC Can you identify patterns of the revolution and rotation of Venus and Earth ? L250
Level 3 5 **Strategic** **Thinking**	L3 ST … for comparisons of the sun, moon and planet? – L40 L3 ST What is happening inside the sun? -L 63 L3 ST compare to planet Earth the mass is 317 times greater, define density? L98 L3 ST consider the concepts of revolution and rotation for planet Earth, by what is it? L 307 L3 ST …cause and effect to understand, compare with Earth and Mars a rotation and a revolution? L 334
Level 4 0 **Extended** **Thinking**	

Appendix H

Ellen's Observation 3 (Highest Learner-Centered Lesson)

Level 1 7 **Recall and** **Reproduction**	L1RR So you are going to have the north pole tilted away, you are going to tell me which season. L12 L1RR Do you know how to graph the results? L79 L1RR Remember the other lab with how much light you get? When did you get the most insolation? For the winter, did New York have a lot of light? L366 & L368 L1RR When is it the warmest? When the Earth is closer to the sun or when far? L418 L1RR Which season is this? What is the number? Which latitude has the most direct sunlight? L436 L1 RR Which latitude is getting the most direct sunlight? Mexico is about which latitude? L529 L1RR What do you notice in the data? Is the earth warmer when closer to the sun? So what makes the seasons? L727
Level 2 8 **Skill and** **Concept**	L2 SC How do you know it is summer? What two things do you know, temperature and light right? L20 L2 SC which hemisphere is receiving the most light? ….L95 L2 SC you are going to have three colors… Which season is this? Which is the coldest? Which is the highest? L146-147 L2 SC Which hemisphere gets the most light? L202 L2 SC Do you think we have seasons because winter, the earth is closer to the earth? What's your winter temperature? And in the summer how far away are you? …Is that farther or closer? L287 & L289 L2 SC what is the equinox? Equal What? Which latitude is getting the most sunlight on the equinox? North pole, south pole, or the equator? L320 L2 SC what about winter and summer? Which one is closer to the sun? …the winter, is it closer to the sun or farther away from the sun? L620 L2 SC No but why did the season change? What did you do? What did you change every time? Did you change the sun? L694
Level 3 4 **Strategic** **Thinking**	L3 ST Why then do we have seasons if it's not the distance? Why did we have different temperatures every time? What did we do? What did you do? Did you move the globe closer to the sun(lamp) every time?L456 & L458 L3ST Do you think we have seasons because the earth is closer to the sun in the summertime? …tell me if you think this is the reason we have seasons? Repeats question with another group What about summer and winter? In summer, closer to the sun or further away? L582 & 584 L3ST …Why do have seasons? Is it because of the distance? So you have to go back to see what we did differently in each station. L601 L3ST …Why did the temperature change every time? What did you change in the experiments? What about the location? Yeah. What did you change? L650 & 652
Level 4 0 **Extended** **Thinking**	

Appendix I

Ellen's Observation 4 (Highest Teacher-Centered Lesson)

Level 1 7 **Recall and** **Reproduction**	L1RR Condensation what does it mean? L14 L1RR Notice what's happening around the humidifier. Touch it, see what is happening, all right? L51 L1RR So, what is the temperature? L119 L1RR What do you notice around here? It's wet. Where's the water coming from? L217 L1RR What is the relative humidity right here? L431 L1RR When it's raining, what is your relative humidity? L439 L1RR You got to do 22, what is it inFahrenheit? L487
Level 2 3 **Skill and** **Concept**	L2SC The vapor? What is the vapor doing? Is the vapor going up or down? L206 L2SC What goes up? When you boil something in your house, how does the vapor goes? Why? What is the temperature? L208 L2SC What is evaporation? …But, evaporation you go from liquid to vapor. Why is that a cooling process? L517
Level 3 4 **Strategic** **Thinking**	L3ST What is the evaporation cooling process? …What does it feel like? L447 L3ST Why is it a cooling process? Evaporation. When you're running outside and you're sweating, does it feel nice? L527 L3ST Does it feel you're getting rid of your heat? Heat is energy, right? L 529 L3ST At home, how do you get water to evaporate, or here? How is that working? Where is the energy coming from? L532
Level 4 0 **Extended** **Thinking**	

Appendix J

Gwen's Observation 1 Reference Point

Level 1 **20** **Recall and** **Reproduction**	L1RR this information is telling you the half-life, so out of this chart, which one does this match? L32 L1RR The disintegration, what does it break into? L40 L1RR We're looking at this chart. Which one of these isotopes is it measuring based upon half-life? L74 L1RR Now, what does carbon break into? Disintegrate into.L79 L1RR What is the isotope that we start with? L89 L1RR So if we start 100%, right? What is half of 100? L133 L1RR That's one-half life. What's half of 50? L137 L1RR So if they give you years 5,700 and 11,400 which one of the isotopes on this chart here that I have here are they talking about? Okay and what does this disintegrate into? L152 L1RR ... What is the number of years that the first half? The number of half-lives, what is that ?... L174 L1RR So what's the stable, what's the name of that element? Does anyone remember N? L187 L1RR Identify radioactive isotope S and the stable disintegration product. So what is it? L201 L1RR What is the stable product again?L249 L1RR So how many years did it take for the sample to decay? L274 L1RR Look over number three. How'd you get four half-lives? L1RR Is 200 breaking in half or is that your starting point? What's the first half life? L378 L1RR Which answer choice best fits?... L417 L1RR Where do you see 25%? Three what? Third half-life or the third box? L508 L1RR now I smashed the rock into four different pieces and I took one small piece, is the age going to change? L523 L1RR look at uranium, it's 4.5 billion years old. How old is Earth? L537 L1RR you look at number six compared to the length of time for the first half life, the sample for the second half life, what does it do? Does that number change? L 630
Level 2 **3** **Skill and** **Concept**	L2SC And what is half of 12.5? There you go you see how it totals 100? Does everyone see the relationship here? L264 L2SC Are they asking for the amount of years? Are they asking you for the amount of half-lives? Are they asking for an isotope? L323 L2SC So we start with 200 right? What's half of 200? L345
Level 3 **1** **Strategic** **Thinking**	L3ST You have a chart and a graph in front of you. Analyze all of the information L15
Level 4 **Extended** **Thinking**	

Appendix K

Gwen's Observation 4 (Highest Learner-Centered Lesson)

Level 1 **1** **Recall and** **Reproduction**	L1RR What would be opposite of cool and dry? L60
Level 2 **8** **Skill and** **Concept**	L2SC What type of weather do we associate with Low pressure? L74 L2SC if we said our low pressure is going to bring our bad weather, if that pressure starts to increase, how will the weather change? L89 L2SC So what else can we use and all the information given to us to help prove that it also won't rain? What about these two numbers? L167 L2SC So it has a high pressure at the station. What else? The what? L203 L2SC There's another one. What else can we use? What do we notice about the numbers for temperature and dew point? L207 L2SC Temperature and dew point, remember the relationship between those two numbers? L317 L2SC So explain what that means. So what do you know that's happening between the two numbers? L346 L2SC So we can infer that skies will possibly clear? Can we predict it might also rain? L393
Level 3 **10** **Strategic** **Thinking**	L3ST So thinking about the difference between high pressure versus low pressure and if air pressure is decreasing, how is the weather going to change? L8 L3ST Look at all of the information in that station model. Okay, so look for two pieces of evidence to prove that it will rain. Yep. And then you're going to choose one of those variables to explain. L38 L3ST So how will the cloud cover being 0%? What do we know clouds influence? You think it's not going to rain in the next five hours. What is one piece of information you have, evidence? L194 L3ST Anyone else who also predicted it was not going to rain? What other pieces of evidence can we use? L199 L3ST So you should have been able to predict that it will not rain within the next five hours with this given information. So choose one of the two that you used and explain it.L214 L3ST How will it help prove that it's not going to rain? Take two more minutes to prove or explain one of your reasons.L245 L3ST So if you take a look at the reasons, if we chose high pressure as our piece of information to explain, what can we say about high pressure to prove that it will not rain? What characteristics do we have during a high pressure system? L275 L3ST So first identify the changes that have taken place from 5:00 AM to 9:00 AM. Then make your prediction or inference if you believe it's going to rain or if skies will eventually clear. L352 L3ST What is the relationship between temperature and dew point, guys? Good, so temperature and dew point. …What do you notice about the difference between these two numbers? What change do we see in temperature? L 377 L3ST So we have 49.5 and 44.2, we're at 48.9 45.8. So we have a greater difference. So do we predict that it will begin to rain or will skies possibly clear? L388

Level 4 **4** **Extended** **Thinking**	L4ET It says analyze all the given data that you had placed into that chart based upon that station model. So all the information that was given to you, take a look at it, predict if it will rain L104 L4ET (restated) So the first thing to do is make a prediction. Will it rain in the next five hours, will it not rain the next five hours? Give two pieces of information on that station model that will prove or help prove your prediction. Write it down. L110 L4ET What I want you to do is use this information to answer the question. So analyze the dew point and temperature over the last five hours, which is provided to you over on the board. How have the temperatures changed over the last five hours? So describe the change that you see in both the temperature and degrees Fahrenheit and the dew point and degrees Fahrenheit. L306 L4ET Explain how they've changed over the last five hours is your first step. So take a look at how your numbers changed from 5:00 AM to 9:00 AM and the temperature, how they've changed from 5:00 AM to 9:00 AM and the dew point. Explain each one. Will Freeport experience rain in the next few hours or will skies begin to clear? Using the information you're assessing. L310

Appendix L

Gwen's Observation 7 (Highest Teacher-Centered Lesson)

Level 1 7 **Recall and** **Reproduction**	L1RR Okay, so if we're burning natural gas, what is that going to produce? L225 L1RR What would power something without any pollution?L234 L1RR So the first one, can I have someone read and answer number one? …So what do we know about density? L270 L1RR So what does convection tell us? What's rising? More dense or less dense air? L275 L1RR Number seven, energy is transferred from the sun to the earth, mainly by? L309 L1RR And number 12, an increase in which gas would cause the most greenhouse warming of Earth's atmosphere? L324 L1RR And then our last one, number nine, which phase change requires water to gain 2,260 joules per gram? L347
Level 2 4 **Skill and** **Concept**	L2SC Which method of energy transfer is primarily responsible for the energy being lost from earth into space? L295 L2SC So if they are looking for the shortest wavelength and you're looking at your spectrum, your visible light spectrum, which color is going to have these shortest wavelength? Out of your four choices? L319 L2SC Number five, during which phase change does water absorb the most heat? L335 L2SC Number eight, which material requires the least amount of energy to change its temperature one degree Celsius per gram? We want to know which one has the lowest specific heat. L341
Level 3 1 **Strategic** **Thinking**	L3ST Number two, which statement is the best example of heat energy transfer by conduction? So what is conduction telling us? L283
Level 4 0 **Extended** **Thinking**	

Appendix M

Carol's Observation 1 Reference Point

Level 1 6 **Recall and** **Reproduction**	L1RR What's the location of each one of them? Pituitary gland, where is it located? Hypothalamus, where is it located? L81 L1RR Name five hormones produced by the pituitary gland. L182 L1RR But what are glands? L183 L1RR Where are the glands of the endocrine system located? Where is the pituitary gland located? Where is the thymus located? Where is the pancreas located? L237 L1RR Question four is asking you to name the major glands of the endocrine system, You're going to list the names of those glands. L1RR And the second part of the question is where are they located in the body? L248
Level 2 3 **Skill and** **Concept**	L2SC What happens to homeostasis? L260 L2SC number 11. It says give an example of a negative feedback mechanism L266 L2SC In this example of negative feedback, what's the function of the insulin? L276
Level 3 2 **Strategic** **Thinking**	L3ST What will happen to a person with improper functioning of an endocrine gland? What do you think will happen? L99 L3ST What mechanism? Feedback mechanisms? Is it a positive feedback mechanism or is it negative feedback mechanism? L135
Level 4 0 **Extended** **Thinking**	

Appendix N

Carol's Observation 9 (Highest Learner-Centered Lesson)

Level 1 8 **Recall and** **Reproduction**	L1RR There are five words. The words are biosphere, population, species, ecosystem, community. How will you organize these words? L5 L1RR Both of them, okay? What else? In addition to the log, what do you see? L83 L1RR What else do you see? Imagine that you're right there. What else do you think you can find there? L97 L1RR Other organisms. Like what? L101 L1RR Biomes are identified by a particular or dominant plant and animal life. What do you see in that map? L165 L1RR Okay. Three things that you learned about the rainforest from the video are? L294 L1RR Absorption of CO2. What else? L295 L1RR there are rainforests in different climatic zones, yes. What else? One more thing. I need one more. L296
Level 2 2 **Skill and** **Concept**	L2SC The biomes, which is our new topic, are part of those ecosystems. Okay? What are biomes? L140 L2SC For example, and the leaves on many of the trees are very broad, Why do you think the leaves are going to be large, like big? Why? Anybody? -----, what do you think?
Level 3 4 **Strategic** **Thinking**	L3ST What do you think? Do you agree, disagree, and why? What organization do you suggest? L19 L3 ST Maybe bacteria. What else? Snakes. Fungi? All right. If you're going to find all of those things there, in which of this categories can we classify those pictures? L115 L3ST El Salvador. What do you think? Tropical? Any other country? DR, El Salvador? Who is from Honduras? What do you think is the biome in your country? L3ST identify location of your home country, what biome is it? You can have one slide, but you need to divide into two countries on the biome. L359
Level 4 4 **Extended** **Thinking**	L4ET This picture here. Tell me, how will you connect, tell me what you see first and then we're going to try to make a connection between what you see and one of this layers in this graphic organizer. What do you see in the picture? L75 L4ET In here, I will like you to think about your country. If you're from DR, what will be your biome, according to this legend? L4ET Adapt to different environments. Very good. All right. Type of flora. What plants are predominant in your biome? You have to provide some pictures L217 L4ET On your presentation, you need to include a title with a name, the map location, climate, very simple, predominant animals and plants, identify location of your home country, and tell me which is the biome of your country. Include a short video that is not more than four minutes long L320

Appendix O

Carol's Observation 7 (Highest Teacher-Centered Lesson)

Level 1 4 **Recall and** **Reproduction**	L1RR what new information did you hear about evolution in that video? What new information that you learned in that video. L10 L1RR The type of skeleton is similar. What else? L60 L1RR First of all, what's evolution? … Define evolution. L72 L1RR What's evolution? Evolution is the change in the inherited characteristic of biological populations over successive generations. L95
Level 2 1 **Skill and** **Concept**	L2SC . At the end of the day, when we see the final conclusion of the video and the discussion is that all organisms on earth do have a what? L 66
Level 3 6 **Strategic** **Thinking**	L3ST What were some of the similarities that they found between these two organisms? What about the DNA? What molecular evidence? What else? What other physical- L28 L3ST What do you need to consider? Global warming, what else? Water level is rising. What else? Humans, there are less species, okay. What else? L127 L3ST There are fossils from different ... that are formed from different processes, and if you read, you properly identify the different processes by which a fossil can be formed. Anybody can mention those? L159 L3ST What did you saw on that video about the whales that help scientists determine relationship between whales and mammals and them having a common ancestor? L207 L3ST in 50,000 years? Or maybe a million years? You need to think about what we do now, today, and how things are changing in the environment. And then think about what type of, as you mentioned earlier, adaptations might develop in order to be successful in that new environment. Okay?L102 L3ST In 50,000 years, if there are going to be changes, what type of Changes do you think will be present? L105
Level 4 0 **Extended** **Thinking**	

Appendix P

Kate's Observation 1 Reference Point

Level 1 **27** **Recall and** **Reproduction**	L1RR You have to let me know if it's meiosis or mitosis. Yes? L11 L1RR What does haploid mean? L85 L1RR One division? Haploid? Listen to the world. H-A. L97 L1RR Since you're telling me that meiosis divides twice, how many daughter cells are made or created?L129 LIRR How many chromosomes are you going to have in each cell? L151 L1RR … fertilization occurs during mitosis, after mitosis, or involving mitosis? Fertilization? L195 L1RR Okay, diploid, but what type of cells? L213 L1RR if you have gametes, what are gametes? L307 L1RR What can you tell me about the reproductive cells, the sex cells, the gametes? What can you tell me about them? L316 L1RR What didn't separate? You just say "they". I don't know what you mean. L726 L1RR What do I call those chromosomes that she said didn't separate? L734 L1RR You're telling me about these homologous chromosomes, right? You remember, I told you you're supposed to have two. What happened? L775 L1RR What is going to result in this extra chromosome? L894 L1RR What is it called when these homologous chromosomes separate? L947 L1RR number of divisions for meiosis, how many times? L 1173 L1RR What about mitosis? How many times? L1177 L1RR How many daughter cells are produced during meiosis, Angelis? L1215 L1RR How many are produced during mitosis? L 1219 L1RR Daughter cells, I want to know if they're different or identical. Meiosis, are the daughter cells identical, L1228 L1RR What about mitosis? Are the daughter cells going to be exactly like the parent cell, or different? L1303 L1RR Meaning, you'd have the diploid number or the haploid number for meiosis? L1323 L1RR Meiosis, the daughter cells, do they have the haploid number of chromosomes, or diploid number of chromosomes? L1333 L1RR Parent cell for meiosis, haploid or diploid? L1371 L1RR What does gametogenesis mean? L1388 L1RR Genesis means the start, the beginning. What does oogenesis? L1433 L1RR What is an ovum? L1457 L1RR What does gametogenesis mean? L1388
Level 2 **6** **Skill and** **Concept**	L2SC On your left, we have me, making of me, meiosis. What do you notice? L529 L2 SC Now, you look at these two and compare, and tell me what do you see? L675 L2SC What if I'm talking about the *Ascarius* worm? What would the full set be? L1361 L2SC Meiosis, if you start with 20, at the end, you're going to have what? L1382 L2SC What can you tell me about those four daughter cells produced by oogenesis? L1496 L2SC What about the sperm? Do you think the sperm will also have four daughter cells, one really big and three small? L1533

Level 3 1 **Strategic** **Thinking**	L3ST You said something about this having three, instead of two. Go ahead, tell me. Explain. We're still on meiosis. Tell me what's wrong. Why do you have three chromosomes there, instead of two? L 709
Level 4 0 **Extended** **Thinking**	

Appendix Q

Kate's Observation 6 (Highest Learner-Centered Lesson)

Level 1 5 **Recall and** **Reproduction**	L1RR look at it, wait, they became a horse? L 126 L1RR And about how old is the modern horse? L337 L1RR Oh, only the bones? L349 L1RR What else do you think is changing? You told me height. That's good. You told me the bones. Yes. What else? L358 L1RR Many different ones? Right? So the study of the structural similarities are L505
Level 2 6 **Skill and** **Concept**	L2SC What do you think is happening here? As the students were examining evolutionary evidence. L122 L2SC So you're telling me that this is old, but what's happening? L333 L2SC So do you understand now that fossils are very important? Why are fossils important? L372 L2SC Like the molecular evidence, like the colors. When I gave you, when I showed you the different colors, they were all green, right? L526 L2SC How is that possible that you get insulin from horses and cows? How are we doing that? L539 L2SC Give me one way to calculate fossil age. What is that called? L701
Level 3 1 **Strategic** **Thinking**	L3ST Why do you think a shark is considered a living fossil? Because what? L409
Level 4 0 **Extended** **Thinking**	

Appendix R

Kate's Observation 9 (Highest Teacher-Centered Lesson)

Level 1 4 **Recall and** **Reproduction**	L1RR Can noise be a pollution? L149 L1RR What is our niche? What do you think our niche is on this planet? L165 L1RR Now if you put a tire in the water, is that going to break down? L319 L1RR So what do you think is happening? What if this is toxic? What if this is toxic? L445 L1RR Do you think will have more toxin in the muscle, in the meat? L446
Level 2 3 **Skill and** **Concept**	L2SC So why is an increase in water temperature considered pollution? Why? L65 L2SC If this is what you asking me, which continent is a continent of garbage? L226 L2SC Organic wastes. Bio-degradable. What does that mean? What does bio mean? L277
Level 3 1 **Strategic** **Thinking**	L3ST You guys heard of the story that came out like about three years or so ago, what about Flint, Michigan? L364
Level 4 0 **Extended** **Thinking**	

Appendix S

Number of Questions at Each Level for Each Observation

Participant	Obs/ lesson #	Appendix	Level 1	Level 2	Level 3	Level 4	Total
Ellen	1	G	12	9	5	0	26
	3	H	7	8	4	0	19
	4	I	7	3	4	0	14
Ellen's Totals			26	20	13	0	59
Gwen	1	J	20	3	1	0	24
	4	K	1	8	10	4	23
	7	L	7	4	1	0	12
Gwen's Totals			28	15	12	4	59
Carol's	1	M	6	3	2	0	11
	7	N	8	2	4	4	18
	9	O	4	1	6	0	11
Carol's Totals			18	6	12	4	40
Kate's	1	P	21	6	1	0	28
	6	Q	5	6	1	0	12
	9	R	4	3	1	0	8
Kate's Totals			30	15	3	0	48
Column Totals			102	56	40	8	