Differentiating between the Different Levels of Inquiry Instruction: Classroom Dynamics that Characterize the Quality of Inquiry Instruction

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Abstract

In the United States, reform movements have been a part of the science education community for decades. Inquiry-based instruction has a long history in reform documents and while it is not explicitly used in the Next Generation Science Standards (NGSS)*, the underlying tenants of this instructional strategy are still evident. Thus, inquiry-based instruction remains a strategy that science teachers can use to address the expectations set forth in the* NGSS. *Therefore, it is crucial that researchers provide science teachers with information concerning the characteristics their inquiry-based lessons should exhibit. This study utilized 5 years of data collected on inquiry-based lessons to search for distinctive patterns between pre-inquiry, developing, and proficient and above inquiry-based lessons. Specifically, we were seeking to describe these patterns in terms of the amount of time spent in the different components of inquiry and levels of student cognitive engagement. We ran ANOVAs with corresponding post hoc tests to determine if distinct patterns existed. Results showed that pre-inquiry lessons spent significantly less time: 1) allowing students to display higher-order cognitive engagement and 2) utilizing the engage and explore components of inquiry-based instruction than did developing and proficient/above lessons. Additionally, pre-inquiry lessons spent significantly more class time in non-inquiry tasks, such as checking homework and engaging students in rote memorization activities, and in the explanation component of inquiry-based teaching. Results also showed that developing and proficient/above inquiry-based lessons displayed significant difference in regards to the amount of time spent engaging students in higher-order thinking skills. Implications of these findings speak to at least proficient inquiry instruction being a viable instructional strategy to accomplish the goals set forth in the* NGSS.

Introduction

Constructivist reform efforts that advocate for actively engaging students in the learning process have been central to science education in the United States for decades (Akcay & Yager, 2010; Anderson, 2007; Atkin & Black, 2007; Talanquer & Sevian, 2014; Wallace, 2012). Further, the *Next Generation Science Standards (NGSS)* (Achieve, 2013) and the *Framework for K-12 Science Education* (National Research Council [NRC], 2012) build upon these reform efforts and demand an even higher degree of student cognitive engagement than past standards.

In order to address NGSS's more rigorous performance expectations for student learning and engagement, instructional strategies must align with these expectations (i.e., students must be challenged to think at higher levels by their teachers and pushed to be engaged in their own learning). In regards to the expectations laid out in NGSS, inquiry-based instruction has demonstrated utility in achieving these expectations in science education (Chang & Mao, 1999; Geier, et al., 2008; Marshall & Alston, 2014). When implemented effectively, inquiry has the potential to increase student conceptual understanding of scientific concepts and engage students at high cognitive levels (Chin, 2004; Smart & Marshall, 2013). However, teachers frequently struggle with effective implementation. Thus,

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professional development (PD) and teacher education programs have sought to assist teachers in facilitating effective inquiry-based instruction.

With its explicit encouragement over the past 20 years (NRC, 1996, 2000, 2012), one would assume that inquiry-based instruction would be prevelant in K-12 classrooms. However, the majority of science teachers do not engage in proficient or exemplary inquiry-based instruction (Capps & Crawford, 2013; Marshall, Horton, Igo, & Switzer, 2009). A vast range exists among science teachers who are facilitating varying types of inquiry-based instruction (Crawford, 2000, 2007; Dreon & McDonald, 2012; Ritchie, et al., 2013) Yet, few studies (Marshall & Horton, 2011) exist that examine the different classroom patterns within inquiry-based lessons that distinguish proficient and above inquiry lessons from those that are still at the pre-inquiry and developing levels. Given the increased expectations of new state and national standards, it is important to search for these existing patterns. Determining these patterns can assist teacher educators and PD facilitators in providing science teachers with more information regarding how to modify teaching to align with proficient inquiry. The current study explores the relationship between the quality of inquiry facilitated in the K-12 science classroom and time spent allowing students to explore scientific concepts at high cognitive levels. The intent is that highlighting these characteristics will provide a picture of what effective inquiry-based instruction, that can attend to the expectations of NGSS, looks like. The following research questions frame this study:

1. What is the relationship between the percentage of time spent in Explore and the level of inquiry instruction (i.e., pre-inquiry; developing; proficient/above) for an enacted lesson?
2. What is the relationship between the percentage of time spent in higher versus lower level of cognitive engagement and the level of inquiry instruction (i.e., pre-inquiry; developing; proficient/above)?

Literature Review

Reform Initiatives and Inquiry-based Instruction

Prior reform efforts such as the *National Science Education Standards (NSES)* (NRC, 1996) sought to increase the rigor of science education while attempting to unite science concepts and processes (i.e., inquiry). However, many states developed standards containing separate inquiry and content standards. Thus, the primary focus became having students simply identifying, summarizing, and, recognizing—lower level forms of cognitive engagement according to Bloom's revised taxonomy (Anderson & Krathwohl, 2001). Currently, the authors of *NGSS* require that students have the opportunity to deepen their level of conceptual understanding by combining scientific practices (i.e., inquiry) and content. As a result, the authors of NGSS get students to apply the content they are learning through modeling scientific concepts, formulating arguments, designing and conducting investigations, analyzing data, and applying mathematical representations—all higher level cognitions according to Bloom's Revised Taxonomy (Achieve, 2013). Thus, the *NGSS* and various state standards have increased the rigor of student learning and instruction. Due to the current expectations of new state and national standards, it is no longer sufficient for students to engage in rote memorization and parrot back information in the same form it was given. *NGSS*, and similar standards, prioritize higher-order thinking (i.e., apply, analyze, evaluate, create) which encourages students engage in the processes of science (Hilton, 2015). Saavedra and Opfer (2012) argue that teachers need to explicitly teach higher order skills in order for students to develop them. Inquiry-based instruction is a teaching method which can develop higher-order thinking skills due to students having to do more of the investigation and explaining of phenomena and applying their knowledge to new context (Blanchard et al., 2010; Yager & Akcay, 2010). Therefore, inquiry-based instruction addresses the increased cognitive expectations of new state and national standards.

Why Inquiry-based Instruction?

In this study, inquiry-based instruction refers to any instruction that engages students in the processes undergone by scientists to find out, better understand, and validate scientific knowledge (Marshall, Horton, & Smart, 2009; NRC, 2012). Affirming, neutral and non-affirming results have been reported involving the impact of inquiry-based instruction on student achievement (Minner, Levy, & Century, 2010). Researchers such as Kirschner, Sweller, and Clark (2006) openly oppose inquiry-based instruction because they feel it overly increases cognitive load for students. However, a multitude of studies have shown positive impacts on student achievement resulting from teaching that displays characteristics congruent with inquiry-based instruction (Chang & Mao, 1999; Geier, et al., 2008; Kaberman & Dori, 2009; Kalu, 2008; Marshall & Alston, 2014; McNeill & Pimentel, 2009). Further, Yager and Akcay (2010) found that teacher participation in inquiry PD may produce positive results in students' concept mastery and students' abilities to apply concepts. In addition to positive effects on student outcomes, effective inquiry instruction can also increase the level students cognitively engage in during instruction (Smart & Marshall, 2013). Specifically, Smart and Marshall (2013) spoke about how inquiry instruction can lead to students explaining and justifying, hypothesizing, and using evidence to formulate conclusions about scientific phenomena—all of which require high cognitive engagement.

Student Cognitive Engagement. As stated above, constructivist learning methods, like inquiry-based instruction, can increase the level at which students engage in higher-order thinking skills (Lai, 2011). Collaborative learning (Thayer-Bacon, 2000), student-centered learning (Lai, 2011), and problem-based learning (Bonk & Smith, 1998) are methods of constructivist teaching found to promote higher-order thinking skills. These instructional methods can encourage students to "take new information and information stored in memory and interrelate and/or rearrange and extend this information to achieve a purpose or find possible answers in perplexing situations" (Lewis & Smith, 1993, p. 136).

Effective inquiry instruction is characterized by students deeply and meaningfully thinking about science concepts (Llewellyn, 2002). Given the more open structure of inquiry-based learning, teacher guidance and scaffolding is important in allowing students the opportunity to achieve higher-order learning goals. Therefore, teachers should be intentional about the questioning and discourse patterns they plan and develop, so students are challenged to engaged in higher-order thinking skills (Chin, 2006; Smart & Marshall, 2013). By advancing from lower-order questions to higher-order questions, teachers scaffold students' progression towards engaging in higher-order thinking. Chin (2006) refers to this process as moving up the "cognitive ladder". While high levels of cognitive engagement are possible with inquiry-based instruction, there are additional features that set apart effective inquiry instruction.

Features of Effective Inquiry-based Instruction

Bell, Smetana, and Binns (2006) suggest that inquiry-based instruction resides along a continuum that spans from confirmatory instruction to open inquiry. Marshall (2013) provides a detailed measure of this continuum by evaluating inquiry-based instruction along a continuum spanning from pre-inquiry to exemplary inquiry for four constructs (instruction, discourse, assessment, and curriculum). Table 1 differentiates the features of various levels of inquiry-based instruction (Marshall, 2013). Confirmatory instruction (i.e., pre-inquiry) is teacher-centered and provides all the information before students investigate science concepts. Open inquiry (i.e., exemplary inquiry) is characterized by students leading the learning process and driving the course of study with teacher facilitation. Structured inquiry (i.e., developing inquiry) moves beyond being completely teacher-centered but still engages students in prescribed or "cookbook" investigations. Guided-inquiry (i.e., proficient inquiry) is characterized by teachers assuming the role of a facilitator and designing experiences that get students to begin constructing their understanding of scientific concepts. Asay and Orgill (2010) contend that different learning goals lend themselves to different types of inquiry-based instruction. While Blanchard and colleagues (2010) agree with this statement, they found that guided-inquiry provides an effective teaching method to achieve expectations set forth in science standards. Additionally, researchers support that requiring students to deeply understand and apply scientific concepts—learning expectations congruent with *NGSS*—can be effectively facilitated through guided inquiry-based instruction (Marshall, 2013; Wilson, Taylor, Kowalski, & Carlson, 2009).

The definition of inquiry-based instruction used in this study, focuses on a more guided-inquiry approach (i.e., proficient inquiry). In guided inquiry, teachers pose a question and the students are responsible for collecting and interpreting the data to answer this question (Schwab, 1962). In guided inquiry, the teacher serves as a facilitator who scaffolds meaningful learning experiences which encourage students to ask questions and make sense of what they are exploring (Crawford, 2000). Guided inquiry can provide authentic problems which cause students to collaboratively grapple with data and engage in scientific processes. Further, guided-inquiry instruction encourages the development and use of models as well as the formulation of explanations from evidence (Bell et al., 2006; Crawford, 2000). The aforementioned experiences that teachers can achieve through guided-inquiry addresses the scientific practices—asking questions, utilizing and developing models, carrying out investigations, analyzing and interpreting data, constructing explanations, communicating information—listed in the *NGSS* (Achieve, 2013). Thus, facilitating guided-inquiry can get students engaging in the expectations set forth in *NGSS*.

Frameworks (e.g., 5E, 4Ex2) designed to support the planning and implementation of inquiry-based instruction typically include an exploration phase that precedes an explanation phase (Eisenkraft, 2003; Karplus & Atkin, 1962; Marshall, Horton, & Smart, 2009; Trowbridge & Bybee, 1996). The exploration phase is characterized by providing students with the opportunity to investigate scientific concepts before they have been explained (Marshall, Horton, & Smart, 2009; Trowbridge & Bybee, 1996). Teachers become facilitators who provide guidance through questioning which ensures students remain meaningfully focused on learning goals. Furthermore, the exploration phase allows for collaborative work where students are encouraged to discuss their reseasoning and think critically about the science concepts they are investigating (Marshall, Smart & Horton, 2011). This study focuses on the exploration phase due to it being a crucial aspect of inquiry-based instruction which starts students on the path of understanding scientific concepts (Marshall, 2013; Trowbridge & Bybee, 1996). Given the teacher role that is required to facilitate effective inquiry-based instruction, teachers often require assistance developing practices that are congruent with this type of instructional strategy (Crawford, 2000).

Developing Teachers to Facilitate Inquiry-based Instruction

Since its explicit inclusion in reform documents (e.g., NRC, 1996, 2000), there has been much time and energy spent developing science teachers to consistently and effectively facilitate inquiry-based instruction (Marshall, Horton, Igo, & Switzer, 2009; Blanchard, Southerland, & Granger, 2009; Crawford, 2000; Lotter, Yow, & Peters, 2014). Given this focus, researchers have developed studies to examine how science teachers progress regarding their facilitation of inquiry instruction following a PD or education program (Smart & Marshall, 2013; Rushton, Lotter, & Singer, 2011; Savasci &

Table 1. Summary of EQUIP Factors by Competency Level

	Instruction	Discourse	Assessment	Curriculum
Pre-Inquiry	Teacher is the center of the lesson and students are passive learners (i.e., taking notes, practicing on their own). Teacher explains all concepts before students are allowed a chance to investigate them and student learning is only focused on mastery of facts, information, and rote processes.	Teacher questioning rarely pushes students beyond the remembering level. This leads to students providing one correct answer or short-answer responses that do not encourage discussion. Teacher controls the communication in the classroom in a didactic pattern. Teacher rarely follows up student answers with more questions.	Teacher does not assess student prior knowledge and encourages learning by memorization and repetition. Students are not encouraged to reflect on their learning. Only factual and discrete knowledge are formally and informally assessed and teacher solicits predetermined answers from students that require little explanation or justification.	The lesson superficially covers content and does not engage learners in activities or investigations. No inquiry was present and the lesson was only focused on content. Teacher prescribes how students organize and record information.
Developing Inquiry	Teacher is the center of the lesson and uses lecture or demonstrations frequently to explain concepts. All activities are verification, however, teacher provides students a chance to explore before he or she explains concepts. Teacher acts as a facilitator at times and students are active learners to a small extent. Student learning focused on mastery of facts and process skills—not conceptual understanding.	Teacher questioning rarely pushes students to the understanding level. This provides some opportunities for open-response answers but focuses largely on one correct answer. Discussions and investigations are unsuccessfully attempted. Communication typically controlled by the teacher—mostly didactic pattern but occasional input from the students. Student answers occasionally followed up by teacher or another student with a lower-order thinking probe.	Teacher assesses students' prior knowledge but does not modify instruction based on the knowledge gained. Learning activities lack critical thinking and focus on product- or answer-focused learning. Students are encouraged to reflect on the learning but only at a minimal level. Teacher uses formal and informal assessments to measure mostly factual, discrete knowledge. During instruction, teacher collected information from students to check understanding.	Teacher provides a lesson that contains some depth of content but makes no connection to the big picture. Activities provided by the teacher are prescribed, content-focused, and there are few chances for inquiry to occur. Students were given only minimal input in how to organize and record information.
Proficient Inquiry	Teacher occasionally lectures and frequently acts as a facilitator. Students are allowed to explore before an explanation occurs and are involved in the explanation process. This allows students to be active learners and develop conceptual understanding of science concepts. Student learning requires application of concepts and process skills in new situations.	Teacher questions challenge students up to the application or analysis level and this encourages students to explain and/or justify their answers. These types of questions allow the teacher to successfully engage students in open-ended discussions and/or investigations and results in a conversational communication with student questions sometimes guiding the discussion. Student responses often followed up with probe from teacher or another student that requires justification for reasoning or evidence.	Teacher checks for students' prior knowledge and partially modifies instruction based on the knowledge gained. Learning activities required critical thinking and encouraged process-focused learning. Students are encouraged to reflect on their learning at an understanding level. Formal and informal assessments use both factual, discrete knowledge and authentic measures. The teacher collects information from students to assess understanding during instruction and modifies instruction accordingly.	Teacher provides a lesson that contains depth of content and there is some significant connection with the big picture. Students are allowed flexibility in investigations. Teacher uses inquiry to address content. The teacher regularly gave students the opportunity to organize and record information in nonprescriptive ways.
Exemplary Inquiry	Teacher occasionally lectures but consistently and effectively acts as a facilitator. Students are allowed the opportunity to explore concepts before they have been explained and these explorations lead to strong conceptual understanding and the chance for students to frequently be active learners. Student learning requires a depth of understanding.	Teacher questions at a variety of levels including analysis level or higher. Level of questioning is used to scaffold learning. Teacher questions require that students justify or explain answers, and students and teacher are expected to critique and challenge others' responses. Teacher consistently and effectively engages students in rich open-ended questions, discussion, investigations, and/or reflections. Communication in the classroom is conversation and student questions often guide the discussion.	Teacher checks for students' prior knowledge and modifies instruction based on the knowledge gained. Learning activities required critical thinking and connections to other concepts and encourages process-focused learning. Students are encouraged to reflect on their learning at various points in the lesson. Additionally, reflection challenges students to think at higher levels. Teacher consistently and effectively uses authentic measures for formal and informal assessments. Teacher also frequently and effectively checks for student understanding and adjust instruction accordingly. Teacher also challenges students' claims and encourages curiosity and openness.	Lesson provides depth of content and there are significant and explicit connections made to the big picture. Teacher consistently and effectively unites learning of content with inquiry and also allows flexibility for students to design and implement their own investigations. Students organize and record information in nonprescriptive ways that allow them to effectively communicate their learning.

Berlin, 2012; Supovitz, Mayer, & Kahle, 2000). Inquiry-based teaching can take a significant amount of time to develop due to this instructional strategy requiring teachers change their positionality (i.e., the sole owner of knowledge and learning) and allow students to become part owners in the learning process (i.e., student-centered instruction) (Hollbrook &

Kolodner, 2000; Magnusson & Palincssar, 2005; Supovitz & Turner, 2000). Many science teachers do not have experience teaching and learning in inquiry-based classrooms, hence their knowledge of how to facilitate these types of learning environments is limited (Anderson, 2007; Blanchard et al., 2009; Capps & Crawford, 2013; Trumbull et al., 2005).

Given the limited experience many teachers have with inquiry-based instruction, PDs are developed to support teachers in adapting or transforming their instruction. PD characteristics that effectively change teacher practice include: actively engaging participants, having highly qualified PD facilitators, and having access to long-term support (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Further, the combination of multiday workshops and continuous monitoring can significantly impact teacher instructional practices because teachers receive consistent and continual feedback from experts (Sunal et al., 2001). Along with the PD characteristics listed above, when providing insights regarding how to change science and mathematics teachers' instructional practice to align with inquiry-based instruction, Marshall and colleagues (2009) suggest having multiple teachers from a school involved in a PD. This cohort model assists teachers in having a support structure within their school so they can discuss and reflect upon the challenges they face. Additionally, researchers suggest providing time for teachers to reflect on their current teaching to determine if a change in their practice is necessary—a process referred to as problematizing practice. If teachers can see their practice needs to change, they will take more ownership in the change process.

Methods

Context and Participants

This study includes data from a five-year PD program that sought to increase the quality and quantity of middle school science teachers' inquiry-based instruction. Teachers in this study were employed in a rural school district. The program provided teachers with two weeks of training in the summer, four group-follow up sessions during the academic year, an average of four full class observations with debriefing afterwards, and numerous individual support sessions. During the summer PD, teachers were engaged in a variety of activities to help facilitate their growth in planning and implementing inquiry-based instruction. Activities included: 1) PD facilitators modeled examples of inquiry-based instruction, 2) teachers and PD facilitators engaged in post-model lesson debriefs, and 3) PD facilitators supported teachers in developing new inquiry-based lessons in teams. Model lessons varied and focused on concepts in physics, chemistry, and life science. Additionally, these lessons exhibited scaffolding questions, collaborative learning, and how to facilitate an exploration before an explanation. These lessons were planned and implemented using the 4Ex2 Framework (Marshall, Horton, & Smart, 2009). While inquiry lesson frameworks (e.g., 3E, 5E, 4Ex2) were all designed with a similar philosophy of having students explore before they explain, the 4Ex2 was used because it explicitly embeds formative assessment and teacher reflection (i.e., "x2") during the engage, explore, explain, and extend phases (i.e., "4E"). Using formative assessment considerably increases student learning (Bell, 2007) and the 4Ex2 makes sure teachers are embedding formative assessments throughout their guided inquiry lessons and not just focusing on designing a summative assessment (i.e., the final "E"). Participating teachers engaged in the lessons as if they were students and once lessons were completed were prompted to reflect on the lessons with questions provided by the PD facilitators (e.g., How is what you experienced different from what we typically see in science classrooms? What were the roles of the teacher and the students? What scaffolds were given to assist students in exploring before an explanation was provided?). These debriefs sought to help teachers better understand the tenets of guided inquiry-based instruction so they could plan inquiry lessons using the 4Ex2 Model. Planning of inquiry lessons was a collaborative task accomplished among teachers who taught the same grade. The PD facilitators served as guides and resources during this process. While the summer served as an immersive PD program, support was also provided during the academic year and included PD facilitators engaging with teachers to co-plan, co-teach, and observe and debrief inquiry lessons.

Each year participating teachers came from one of two to three partnering schools and priority was given to high-needs schools (as defined by the state). Participants were expected to complete at least one year of PD with most participating for multiple years. Inquiry-based instruction is an admittedly challenging instructional strategy to implement and master (Blanchard et al., 2010; Crawford, 2000) and therefore multiple years were advocated by the PD facilitators. All cohorts received parallel instruction on the 4Ex2 Instructional Model by the same instructor. While the two-week summer PD and the supports during the year differed slightly each summer and for teachers enrolled in multiple years, the focus consistently remained on increasing the quality of inquiry-based instruction. Second and third year participants focused on honing in on specific aspects of their instruction, planned additional inquiry-based lessons, engaged in additional model inquiry lessons and debriefing sessions, and served as mentors for the first year participants. Additionally, second and third year teachers were expected to hold workshops for the teachers at their own schools or districts.

Since the research questions focus on the individual patterns seen during each lesson enactment and not patterns among individual teachers, the unit of analysis in this study is the individual enacted lessons by the participants (N = 424). Thus, our data set contained a wide array of lessons in regards to a variety of factors (e.g., grade level, content, PD intervention year, teaching experience). This allowed us to determine the general patterns that existed among these lessons regardless of the differences. Lessons ranged from 45 minutes to 90 minutes in duration depending on the different school schedules. These lessons were obtained from observations involving 50 middle school science teachers. Of the 50 teachers, 36% completed one year of PD, 52% completed two years of PD, and 12% completed three years of PD. The average teaching experience of the all the teachers involved was 13.16 years, with the minimum being one year and the maximum being 36 years. Teachers were observed an average of 3.58 times each year involved in the intervention.

Observation Instrument

The Electronic Quality of Inquiry Protocol (EQUIP) was the instrument used to evaluate the quality of inquiry-based instruction facilitated in each lesson. Teachers were formally observed at least four times (typically once each nine weeks) during the year(s) they were involved in the program.

The EQUIP is highly valid and reliable (Marshall, Smart & Horton, 2011). Specifically, EQUIP showed a high internal consistency (Cronbach's alpha ranged from .820-.912 for the various constructs and overall lesson score (*N = 102*). The EQUIP also has moderate to substantial interrater reliability (Cohen's kappa .51-.64 for 16 paired observations and coefficent of determination .856 of A predicting B's score and vice versa) and a well substantiated face, content, and construct validity (using the research literature, a review panel, and a confirmatory factor analysis). The EQUIP observation protocol consists of three main sections. The first section attends to the basic demographic information of the teacher being observed (e.g., ethnicity, number of years teaching) and class/lesson descriptions (e.g., number of students in the class, lesson title, standards addressed). The second section describes how class time is used in five-minute intervals (e.g., activity code, cognitive code, inquiry instruction component). The third main section measures four factors of inquiry instruction: assessment, instruction, discourse, and curriculum (Marshall, Horton, & White, 2009). This section is also where an observer provides a score for each factor (e.g., instruction, assessment) and an overall lesson score with justification for the score given. Table 1 provides a condensed summary of the third major section of the EQUIP (https://www.clemson.edu/education/research/centers-institutes/inquiry-in-motion/research-evaluation/equip.html).

This study focuses on data collected in the second major section geared towards describing how class time is used. In this section, observers collect data at five-minute intervals, starting at the beginning of class and ending at the end of the observed lesson. This study centers on the five-minute codes regarding student cognitive engagement displayed by the students and inquiry behaviors facilitated by the teacher (see Figure 1 for the description of each). Cognitive engagement was measured by observers noting what students were having to do during each five-minute interval. If students were engaged in mainly recall or understanding science concepts during a five-minute period in the class, the observer would score the cognitive code as a 2. In five-minute intervals, if students were observed applying, evaluating, or creating, the observer would score a 3, 4, or 5, respectively. Similarly, observers would note what the class was doing and note which inquiry component code (i.e., which phase of inquiry) was exhibited during each five-minute interval of a class. If the class was investigating a new science concept during a five-minute period, the observer would code this as 2 or "explore". If the students and/or teacher were making sense of an activity during a five minute interval, this was coded as 3 or "explain".

Data Analysis

Lessons enacted by the participants were grouped using the overall lesson score. This score was assigned after the entire lesson was observed and took into account the second and third sections of the EQUIP. Lessons were put into three groups: pre-inquiry (lessons earning an overall score of 1: n = 54), developing inquiry (lessons earning an overall score of 2: n = 195), and proficient/above lessons (lessons earning an overall score of 3 or 4: n = 175). Since the amount of time of each lesson varied, percentages of five minutes codes were used in determining the different patterns that the lessons exhibited (e.g., % of time spent in explore). As the exploration phase in inquiry-based instruction is a key component which allows students to achieve the increased cognitive expectations stated in the NGSS, only the Explore Inquiry Codes and Cognitive Codes were analyzed. The Cognitive Codes were collapsed into two groups: a lower order group comprised of receipt of knowledge and lower order codes and a higher order group comprised of apply, analyze, and create codes.

Cognitive Codes – Displayed by Students	Inquiry Component Codes – Facilitated by Teacher
0. *Other*: Classroom disruption, non-instructional portion of lesson, administrative activity	0. *Non-inquiry:* Activities with the purpose rote memorization of facts; drill and practice; checking answers on homework, classwork with little explanation
1. *Receipt of knowledge*	1. *Engage:* Typically situated at the start of the lesson; assessing prior knowledge and misconceptions; peak student interest
2. *Lower order:* (Recall, remember, understand) and/or activities focused on completion exercises, computation	2. *Explore:* Students investigate a new idea or concept
3. *Apply*: (Demonstrate, modify, compare) and/or activities focused on problem solving	3. *Explain:* Teacher or students making sense of an idea or concept.
4. *Analyze/Evaluate:* (Evidence, verify, analyze, justify, interpret)	
5. *Create:* (Combine, construct, develop, formulate)	

Figure 1. 5-minute Interval Cognitive and Inquiry Component Codes.

ANOVAs were run in order to determine if the different groups of inquiry lessons (e.g., pre-inquiry, developing, and proficient/above) exhibited significant differences in the percentage of time spent: 1) in the exploration phase of inquiry and 2) at higher and lower cognitive levels in which students were engaged. In order to determine between group comparisons for the outcome variables (e.g., percent of time in exploration phase, percent of time in higher order thinking, percent of time in lower order thinking), post hoc tests were conducted when ANOVAs showed signficance. Depending on the results from Levene's Tests, either Tukey's HSD or Games-Howell tests were used.

Results

The first ANOVA showed a significant difference between the three levels of inquiry lessons in the percentage of time spent in the exploration phase of inquiry [$F(2,421) = 16.71$, $p < .001$.] A post hoc test was run to determine which groups differed in the percentage of time spent in the explore phase. Due to a significant Levene's test statistics ($F = 12.05$, $p < .001$), a Games-Howell post hoc test was run to determine the between group differences. Results from the post hoc tests showed that pre-inquiry lessons displayed significantly lower amounts of time in the explore phase ($p < .001$) than developing and proficient/above lessons. Pre-inquiry lessons spent 10% of class time in the explore component versus developing (31%) and proficient/above (36%) lessons. The post hoc test showed that developing and proficient/above lessons did not display a significant difference in the amount of time spent in the explore phase of inquiry. Cohen's d effect sizes ranged from .79-1.03, which is considered high (Keppel & Wickens, 2004). Table 2 reports results from the Games-Howell post hoc test and Cohen's d effect sizes.

Table 2. *Games-Howell Test Results and Effect Sizes of Percent of Time Spent in Explore by Lesson Type*

Lesson Type	Mean	Mean Differences (Effect Size in parentheses) 1	2	3
1. Pre-Inquiry	10.10	0		
2. Developing Inquiry	31.39	21.29*** (.79)	0	
3. Proficient/Above	36.09	25.96*** (1.03)	4.7	0

*p< .05. **p < .01. ***p< .001.

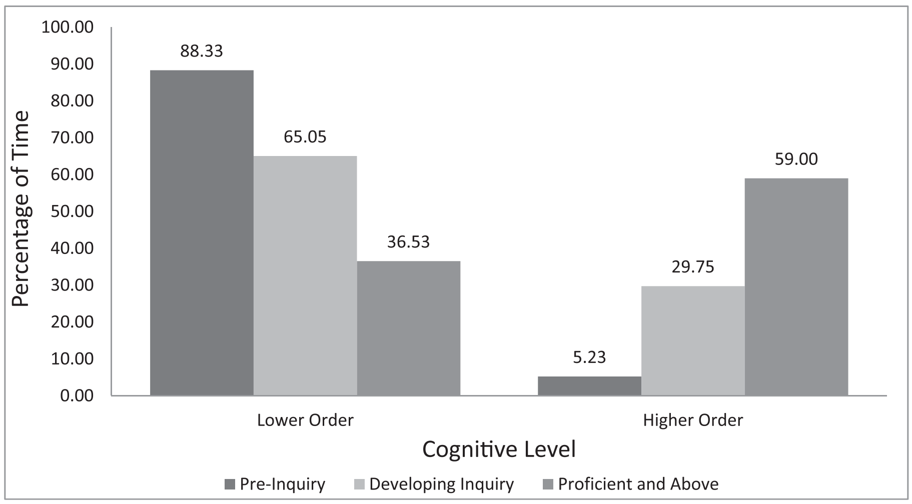

Figure 2. Percentage of Lower vs. Higher Order Think at Different Levels of Inquiry.

The second ANOVA showed significant differences between the 3 inquiry levels and the amount of time spent engaging students at low [$F(2,421) = 82.05$, $p < .001$] and high [$F(2,421) = 93.88$, $p < .001$] cognitive levels. Due to significant Levene's test statistics for both the low ($F = 17.47$, $p < .001$) and high ($F = 23.96$, $p < .001$) cognitive engagement outcome variables, Games-Howell post hoc tests were run to determine the between group differences (See Table 3). Post hoc tests showed that students were engaged in significantly more lower order thinking during pre-inquiry lessons (88%) than developing inquiry lessons (65%) and proficient/above lessons (37%). Further, the post hoc tests found that students were engaged in significantly less higher order thinking during pre-inquiry lessons (5%) than developing lessons (30%) and proficient/above lessons (59%). There were also significant differences between developing and proficient/above lessons in regards to the amount of time spent engaging students in lower and higher order thinking. All significant differences were $p < .001$. Effect sizes ranged from .93-2.34, which are considered high (Keppel & Wickens, 2004).

Discussion

Exploration Phase and Type of Inquiry-based Instruction

Our results show that students were engaged in significantly less exploration of scientific concepts during inquiry lessons facilitated at the pre-inquiry level than those facilitated at the developing and proficient/above levels. This means that during pre-inquiry lessons students were provided few opportunities (10% of class time on average) to engage in process skills geared toward supporting their conceptual understanding of scientific concepts—an explicit expectation of the NGSS (Achieve, 2013; NRC, 2012). Instead, students in these lessons were passive learners who had the majority of science concepts explained to them by the teacher before they were allowed to investigate (see Table 1—instruction factor for pre-inquiry). Our results also indicate that lessons facilitated at the

Table 3. Games-Howell Test Results and Effect Sizes of Percent of Time Spent in Low and High Cognitive Engagement by Lesson Type

		Mean Differences (Effect Size in parentheses)		
Low Cognitive Engagement				
Lesson Type	**Mean**	**1**	**2**	**3**
1.Pre-Inquiry	88.33	0		
2.Developing Inquiry	65.05	-23.28*** (-.93)	0	
3.Proficient/Above	36.53	-51.80*** (-2.12)	-28.52*** (-.94)	0
High Cognitive Engagement				
1.Pre-Inquiry	5.23	0		
2.Developing Inquiry	29.75	24.52*** (1.06)	0	
3.Proficient/Above	59.00	53.77*** (2.34)	29.25*** (.99)	0

*p< .05. **p < .01. ***p< .001.

developing and proficient/above levels displayed similar characteristics in the amount of time students were allowed to engage in explorations before science concepts were explained. Our results support prior research suggesting that effective inquiry-based instruction should include spending at least 30-40% of class time allowing students to actively explore scientific concepts (Crawford, 2000). In so doing, teachers begin to move their instruction from being primarily teacher-centered and prescriptive in nature toward a more guided inquiry approach (i.e., proficient or above inquiry instruction).

Teachers in the current study participated in PD that explicitly highlighted and modeled the goal of providing an opportunity for students to explore scientific concepts before a formal explanation occurred. This training may have led teachers to acknowledge the need for allowing students a chance to engage in the practices of inquiry in order to come to a deeper level of conceptual understanding. Therefore, as teachers worked to transition their practice from pre-inquiry to developing and proficient/above inquiry, there may have been a general focus on allowing for more explore time. However, teachers may not have focused on the quality of the exploration facilitated.

Level of Cognitive Engagement and Type of Inquiry-based Instruction

While the difference in time spent in explore is an important part in progressing in the quality of inquiry instruction, this is only a starting point. Our results suggest that only changing the amount of time exploring is not sufficient if teachers are attempting to move from developing to proficient/above inquiry-based instruction. Another important factor is what students are asked to do during the exploration. Are students encouraged to spend time using higher-order levels of cognitive engagement? The second set of analyses support the idea that proficient/above inquiry-based instruction is characterized by students engaging in higher-order thinking for a significant portion of instruction (Llewellyn, 2002). Figure 2 displays the percentages of time the various levels of proficiency in inquiry instruction spent in lower-order versus higher-order thinking skills. These results suggest that teachers can increase the level of their inquiry instruction by increasing the cognitive complexity of their instruction. Table 1 provides descriptors of the common components found in proficient/above inquiry-based lessons and therefore sheds additional light on how teachers can increase this aspect of their instruction. This goal can be accomplished by posing questions at higher cognitive levels throughout the lesson and developing instructional experiences that require students to think critically about scientific concepts. Further, students should be challenged to apply their learned knowledge in novel situations, construct arguments supported by evidence, evaluate explanations, and engage in process-focused learning. In the current study, proficient/above lessons were typified by students applying, analyzing, evaluating, and creating almost twice as much as they were in developing lessons (see Figure 2). The opposite of this is true for lower-order thinking skills.

As illustrated by Chin's (2006) study, teachers can facilitate their students engaging in higher-order thinking by asking scaffolding questions that require students to think deeper about what they are explaining. In turn, lower-order questions should not be completely removed from instruction, as they are critical in supporting student engagement with higher-order questions. Smart and Marshall's (2013) study agrees with Chin's (2006) findings regarding follow-up scaffolding questions. However, it expands this idea by describing other discourse patterns that are linked to students engaging in higher levels of cognitive engagement. The results from Smart and Marshall's (2013) study indicate that proficient/above inquiry lessons were often typified by classroom interactions which were conversational, allowed students to reflect on what they were investigating, and pushed students to justify, reason, explain, and apply their knowledge.

Implications for Professional Development

It is crucial that PD facilitators highlight the necessity of providing students with sufficient opportunities to collaborate with one another to investigate concepts before they are explained (Marshall, 2013). Therefore, time should be spent developing teachers' abilities to modify current labs and activities so they can occur before explanations. Further, reinforcing and modeling the idea of following each exploration with an explain phase is an important piece of PD. This shows how to provide balance and an opportunity for the teacher to guide students to make sense of scientific content. Without the explain phase of inquiry-based instruction, teachers run the risk of facilitating "activity mania" type classrooms where students participate in activities that lack developing conceptual change. By allowing time to make sense of explorations, teachers transition their instruction to focusing on students' development of conceptual understanding (Marshall, Horton, & Smart, 2009).

While the amount of explanation time is important, the quality of the time is also an essential component. Therefore, PD programs should focus on improving the quality, as well as, the quantity of inquiry-based instruction. Teachers often struggle with designing scaffolds that increase the quality of their instruction and move students from lower-order thinking to higher-order thinking (Chin, 2006). Accordingly, PD on inquiry-based instruction should focus on training teachers to ask effective questions at a variety of cognitive levels. In addition, PD facilitators should model the process of developing questions that can scaffold students up the "cognitive ladder" to support their conceptual understanding. Chin (2004) discusses how "productive questions" that move from concrete to more abstract ideas allow students to move forward in their thinking and understanding. Productive questions include those which focus students' attention on details they may have overlooked; require students to predict; integrate and apply their knowledge; make students search for cause and effect relationships; and encourage students to think about quantitative as well as qualitative ideas. PD facilitators should push teachers to think about and plan questions that attend to these different aspects. Providing coaching on developing planned questions that can scaffold students during their learning experiences can reduce the cognitive load teachers experience when attempting to facilitate guided inquiry-based lessons.

It is crucial that students engage in higher-order thinking skills so they can be prepared for future schooling, careers, and life in general (Hilton, 2015; Levy & Murnane, 2005). Employers are searching for individuals who can think critically and creatively, problem solve, collaborate, access and analyze information, and effectively communicate (Wagner, 2008). The demands of many of the newer state standards and the *NGSS* (Achieve, 2013) are focused on students engaging in 21st Century Skills, such as higher-order thinking skills (Hilton, 2015). Therefore, it is important to search for instructional strategies teachers can use to achieve these goals. For the population studied, this study demonstrates that inquiry-based instruction is a strategy that can help achieve these goals, especially when enacted at the proficient/above level. Further studies are needed to see how well these results generalize to other populations. Additionally, it is not known from this study whether inquiry achieves these goals better than other instructional strategies.

Admittedly, facilitating inquiry-based instruction requires a significant pedagogical shift for the teacher. Crawford (2000) argues that inquiry-based instruction requires the greatest amount of teacher involvement due to the activities of planning, scaffolding, monitoring, and modeling that teachers must engage in during the implementation of this strategy. This study highlights how teachers can, at least partially, begin to move their practice toward more effective guided inquiry-based instruction by focusing on two key characteristics of inquiry instruction—amount of time allowing students to explore and amount of time challenging students in higher-order thinking.

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