

THE EFFECT OF THE 5E INSTRUCTIONAL MODEL ON STUDENT
ENGAGEMENT AND TRANSFER OF KNOWLEDGE IN A 9th GRADE
ENVIRONMENTAL SCIENCE DIFFERENTIATED CLASSROOM

by

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ABSTRACT

This action research project evaluates the effectiveness of the 5E instructional model in a 9th grade environmental science classroom to engage students and improve their ability to apply scientific knowledge to new situations. In this study the 5E instructional model was compared with the traditional approach of the direct teach instructional method. Student assessments, surveys, and interviews were used to gauge whether the 5E instructional model aided in student ability to apply knowledge and engage in classroom experiences. Teacher observations, an engagement tally, and teacher journals were also utilized to evaluate teaching effectiveness and student learning. In this study, the role of the teacher in the classroom within these two instructional models was compared. This study indicated a slight advantage of using the 5E instructional model over direct teach, however both methods of instruction can be effective tools in classroom teaching.

INTRODUCTION AND BACKGROUND

Students in my classroom find it challenging to transfer the information they have learned to new situations. In the early stages of my career I utilized the direct teach method of instruction to communicate new ideas with my students, which placed me, the teacher, at the center of the classroom rather than my students. The direct teaching model emphasizes the practice of teachers providing a short lecture followed by guided and independent practice as outlined in Table 1. In this action research project, I utilized an inquiry-based learning model, the 5E Instructional Model, which gives students greater opportunities to develop their own understanding of concepts over time. I wanted to see if this improved the ability of students to transfer their knowledge to new situations. This teaching model outlines five essential steps for instruction: engage, explore, explain, elaborate, and evaluate. This method allowed for more student engagement in the classroom by allowing my students to do science rather than watch science.

Table 1
Comparison of Direct Teach and 5E Instructional Models

Direct Instruction Teaching Model	BSCS 5E Instructional Model (Guided Inquiry)
Anticipatory Set: activates student interest	Engage: students engage in an activity which prompts them to question what they think they know
Link: connection to what has been previously learned	Explore: students must test a question or problem
Presentation: teacher presents and explains lesson concepts	Explain: students are given the opportunity to learn a concept or skill with teacher guidance
Guided Practice: students are given the opportunity to demonstrate knowledge under teacher's guidance	Elaborate: students apply the new concept or skill to a new situation
Independent Practice: students practice concept or skill individually	Evaluate: students demonstrate skill or concept individually

By giving students opportunities to be actively involved in their learning, I hoped they would be able to develop a deeper understanding of the concepts and apply what they have learned to new situations. My action research question was: how does a student-centered learning experience through the 5E Instructional Model influence the ability of students to apply scientific knowledge in a differentiated classroom? (Table 2).

Table 2

Research Questions

Research Question:
How does a student-centered learning experience through the 5E instructional model influence the ability of students to apply scientific knowledge in a differentiated classroom?
Sub Questions:
1) How does use of the 5E instructional model influence the ability of students to apply scientific knowledge to new situations?
2) What affect does the 5E instructional model have on student engagement in science?
3) How will a student-centered approach, using the 5E instructional model change my role as a teacher within the classroom?

I work at Brewster Academy, a small boarding school in Wolfeboro, New Hampshire, which emphasizes the best practices of mastery-based learning and differentiated instruction. In mastery-based learning students must demonstrate learning by earning 80% or higher on assessments. If a student does not meet this criteria, then he or she is required to participate in one-on-one instruction to relearn the material and achieving mastery before moving on to the next topic in the curriculum. Differentiated instruction allows for students of all abilities to be included in one classroom. In differentiated instruction lessons are tailored to match the individual needs of students by adjusting teaching style and delivery to suit the needs of advanced and lower achieving

students alike. Each class differentiated into three levels (foundational, standard, and accelerated) based on skills and performance, which informs me of their level of readiness for understanding deeper concepts. During this study there were thirteen students (26%) at the foundational level, thirty-two students (64%) at the standard level, and six students (12%) at the accelerated level. Since all of these levels are within the same class, the strengths of each are valued and students are encouraged to engage in cooperative learning. At the end of each trimester the levels of students are evaluated to give opportunities for each student to find the right level of challenge as the year progresses using the criteria in Appendix A. During this study, two students moved into the accelerated level and one student moved from the foundational to the standard level. All students are required to earn mastery (80%) on major topics and skills before moving on in the curriculum. For students earning grades below mastery, a dedicated period at the end of each academic day allows for teachers to be available for extra help and re-teaching of concepts.

The fifty students in my ninth grade Environmental Science classes bring a range of learning styles and abilities with 25 students (50%) participating in a specialized instructional support program and eight students (16%) learning in a second language. Students learn in a small class environment with 14 or fewer students per class and this allows for greater investment of time and resources in developing the skills of all students within my class.

This study allowed for a better understanding of the effectiveness of an inquiry-based teaching practice for students at my school as this form of instruction may become

a core component of our best practices at Brewster Academy (Eldredge, 2016). This study provided helpful feedback on the strengths and challenges of utilizing inquiry within a classroom for me and my colleagues. I believe my school provides a perfect setting for incorporating inquiry into the classroom as it serves the individualized needs of the population of students with whom I work and allows me to better reach the needs of my students.

CONCEPTUAL FRAMEWORK

Scientific inquiry is an educational tool that promotes critical thinking through investigation of a question or problem (Llewellyn, 2008). The concept of inquiry is rooted within the ideas of Jean Piaget, who acknowledged the sequence by which children internally revise their thinking about how the world works through natural learned experience and observation (Piaget, 1986). From his studies of children and how they perceive the world, he surmised that children's accumulation of knowledge is constructed over time and this adaptation allows children to apply what they have observed to challenges imagined (Piaget, 1986). For example, children can recognize the difference between the physical effort of running 200 feet versus a thousand without having to run these distances every time they are trying to compare them. They can build a mental model comparing the two without the need for running through their past experiences with distance and observations of the physical exertion required. This idea of constructing knowledge and building understanding was first brought to the world of science education through John Dewey, who believed in allowing students to learn through experience and reflection (Barrow, 2006; Bybee, 2015).

Dewey believed in connecting students' hypotheses, subsequent experiences, and conclusions through reflection (Bybee, 2015). Dewey understood that classroom experiences needed to give students opportunities to develop the skills they will need in their future lives and the importance of supporting teachers equipped to prepare students for these challenges (Dewey, 1986). This approach to education captures the ideas of inquiry, as it becomes not only a way to understand the world, but a mechanism for building meaning within understanding. By giving students opportunities to become more engaged with their learning, they will have the opportunity to better develop a growing body of experience and critical thinking skills that will allow them to tackle future problems (Dewey, 1986). However, education needs to ensure that learning experiences result in students creating understanding that is accurate and for this reason teachers need to provide opportunities for students to experience phenomena and make connections between one lesson and the next (Dewey, 1986). Likewise, there needs to be a structure that connects these learning experiences in a way that builds deep understanding (Dewey, 1986). In constructivist learning, "...students bring their current explanations, attitudes, and skills to a learning experience. Through meaningful interactions with other individuals and their physical environment, which includes students and teachers, they redefine, replace, recognize, and reconstruct initial explanations, attitudes and skills" (Bybee, 2015, p. 29). Thus, the teacher becomes a facilitator or guide within the process of learning rather than a source of information (Barrow, 2006; Llewellyn, 2008; Bybee, 2015).

To deliver meaningful inquiry experiences, the 5E model was developed by Rodger Bybee, which combined prior learning cycle models including Dewey's instructional model and Atkin and Karplus' learning cycle (Bybee, 2015; Sickel, 2015). The 5E model gives educators the opportunity to utilize a series of cyclical steps to incorporate inquiry within lessons. In the 5E Model students engage, explore, explain, elaborate, and are then evaluated (Bybee, 2015). This helps provide students with the valuable, quality experiences Dewey describes (1986). "Creating teachable moments" becomes the goal of the teacher with this model and students are central to their own learning experiences within a carefully constructed learning progression in which students must adjust their understanding over time as they infer from their observations (Bybee, 2015, p. 21). In reflecting on phenomena that challenges prior assumptions, students are able to question their own previously held ideas and revise their thinking to better understand phenomena (Dewey, 1910). This type of learning, while focused on individual conceptual change, offers great opportunity for cooperative and collaborative learning as well. One formative assessment technique, misconception probes, allows for students to work through this conceptual change using their own prior understanding throughout the lesson and shifting incorrectly held assumptions through the exploration of a concept (Black & William, 1998). Black and William (1998) argue that misconception probes are an effective means of assessing learning and allow for greater gains in student understanding. This type of assessment dovetails with the framework of the 5E instructional method especially in the engage, explore, and explain steps of the

process, however it can also be implemented in a direct teach lesson in the anticipatory set.

While inquiry has a rich history within scientific teaching, the term carries some ambiguity in what skills it describes in the context of learning. While the general use of the term has been coined in education to describe investigation or questioning, the skill set it includes varies depending on the context in which it is used. To identify science skills associated with this term, the National Science Education Standards and National Research Council provided clarification on what inquiry means and the skills they hope both teachers and students alike will be able to develop (Barrow, 2006; National Research Council, 2000). Skills critical for inquiry instruction in the high school age range include

Identifying questions and concepts that guide scientific inquiry, designing and conducting scientific investigations, us[ing] technology and mathematics to improve investigations and communications, formulat[ing] and revis[ing] scientific explanations and models using logic and evidence, recognizing and analyzing alternative explanations and models, and communicat[ing] and defending a scientific argument, while also understanding how these inquiry skills inform our understanding of the nature of science (Inquiry in the National Science Education Standards, 2000 pp.19-20).

Likewise, the skills described closely match those in the Next Generation Science Standards cross-cutting concepts. Despite the wide range of skills encompassed within this list, they share a common thread; the key to inquiry is utilizing questions as a way to frame students' learning opportunities (Barrow, 2006). In this action research project, inquiry will be defined as a means of questioning phenomena and revising prior thought to incorporate newly integrated knowledge. To properly implement inquiry in my

classroom I used the 5E instructional model as outlined by Rodger Bybee for guided inquiry (2015).

While the 5E instructional model provides a framework to create experiences for students to engage in inquiry, there is a continuum of difficulty of both the inquiry experiences and the role of the teacher and student within these experiences (Colburn 2000b; Llewellyn, 2008). The activities can range from being open, which allows students to self-direct learning through development of their own question to answer through investigation, to demonstrated inquiry, in which teachers provide the question, resources, and results of a problem (Colburn, 2000b; Llewellyn, 2008). Between demonstrated and open inquiry is guided inquiry, which will be the core focus of my action research project. Guided inquiry allows students to tackle a question posed by the teacher with provided materials or procedures but unknown outcomes (Colburn, 2000b; Llewellyn, 2008). The guided inquiry process gives students the opportunity to communicate and interpret findings (Colburn, 2000b; Llewellyn, 2008). Guided instruction provides the best opportunity for student growth within the classroom, while use of open inquiry has been less effective in settings where students have little background knowledge or experience (Kirschner et al, 2006). Without guidance students run the risk of developing new misconceptions (Kirschner et al, 2006). Students within my class fall within the category of students relatively new to understanding the concepts I teach, so guided inquiry best met the needs of my students.

Several studies have attempted to capture the benefits of inquiry-based methods on student understanding. One study found that inquiry has the greatest benefits for high

school students in learning goals including knowledge, reasoning and argumentation in comparison to commonplace science teaching practices (Wilson et al, 2010). Crawford (2000) found that inquiry works best when it is relevant for students and provides “authentic problems.” In this project I tried to capture students’ interest through the use of real-world applications and examples, as this would give students the ability to practice finding solutions of problems they may encounter within their lives.

In regards to student performance across a differentiated curriculum, one study suggested inquiry-based learning “enhance[s] the learning of the less-advantaged students” (White & Frederiksen, 2000). White and Frederiksen (2000), found that students using the ThinkerTools Inquiry Project, a science-based curriculum, were able to demonstrate improvement across all levels, with the greatest benefits being for those students typically considered lower-achieving than their peers when paired with a reflective process.

Student attitudes toward learning in inquiry-based instruction compared to traditional instruction methods have shown promise. In a study analyzing the diaries of students responding to both inquiry and traditional teaching methods, students in the inquiry group wrote richer journal entries and asked a greater number of higher-order thinking questions (Kawalker, and Vijapurkar, 2015). The same study included video recordings in which students in the inquiry group demonstrated greater engagement within the class (Kawalker and Vijapurkar, 2015). The active learning provided by inquiry instruction in this study allowed for students to feel more involved in their learning experience and resulted in greater willingness to embrace the process of

considering higher-order questions within the class (Kawalker and Vijapurkar, 2015). However, as noted by the authors, this method needs to be used in conjunction with other methods of assessment to evaluate whether student knowledge depth was retained (Kawalker and Vijapurkar, 2015).

A teacher's philosophy of teaching and perceptions can shape how curriculum is delivered (Sickel, 2015). Often personal experiences and beliefs about best practices inform how a teacher perceives their role within a classroom. Inquiry instruction can provide teachers with the opportunity to alter their role within the classroom from the center of attention to a guide and facilitator of learning (Lebak and Tinsley, 2010; Crawford, 2000). To achieve this transformation in classroom culture, it is crucial to involve cooperation and collaboration with students and colleagues (Lebak and Tinsley, 2010). Lebak and Tinsley (2010) noted teachers and students simultaneously follow a progression of learning as the classroom evolves to becoming student centered; the process requires growth in the teacher as new the methodology of instruction is implemented. "Teachers engaged in inquiry are in turn likely to engage their students in inquiry" (Lebak and Tinsley, 2010, p. 967).

In observing teachers who effectively incorporate inquiry within their teaching practices six characteristics have been identified (Crawford, 2000). An inquiry-based classroom should include "situating the instruction in authentic problems, grappling with data, collaboration of students and teacher, connection with society, teacher modeling behaviors of a scientist, and development of student ownership" (Crawford, 2000, p.922). To master these six characteristics, a teacher will need to show great investment in both

their own learning and that of their students; the efforts required by inquiry-based instruction are great as are the rewards. Teachers who engage with inquiry-based practices tend to model these skills in their interactions with students by allowing students to develop evidence for their assertions and encouraging ideas that challenge previously held beliefs (Liu et al, 2010). It is therefore, not surprising that teachers with “inquiry-based attitudes” tended to be more reflective and self-aware of their own practices and kept abreast of changing ideas within their field (Meijer et al 2016, pp. 74).

Teachers are challenged by finding ways to assess inquiry experimentation as the outcomes of an experiment may vary greatly among students who may still accomplish the learning task goals (Emden and Sumfleth, 2014). However, the opportunity to address unexpected outcomes allows students to genuinely engage in real scientific experiences; the purpose of science is not to find the only answer, but to evaluate possibilities using evidence. The method of inquiry is at the core of the process of doing science.

METHODOLOGY

Demographics

At the beginning of this project there were fifty students in my Environmental Science class. During the data collection phase of this project, two students decided to withdraw from the school. Each class contained between ten to thirteen students. There are twenty-six males (54%) and twenty-two females (46%) in environmental science. Of these students, there are thirty-four (71%) boarding students and fourteen (29%) day students. There are ten (21%) international students and thirty-eight students (79%) from

the United States. The class contains 25 students (50%) participating in a specialized instructional support program and eight students (16%) learning in a second language. While the school hopes to include students of many backgrounds, the class is predominately white (69%) with a few students of color (10%), and several students from Asian countries (21%). Students at the school have a middle-to-high socioeconomic backgrounds, however it is important to note that many students receive significant scholarships in order to attend. The current tuition, without scholarship is \$59,900 for boarding students and \$35,020 for day students. The instructional support program is an additional cost ranging from \$3,700 to \$10,800 depending on the level of need. International students have an additional fee of \$1,550 and students enrolled in the English as a Second Language program pay up to \$8,400 above the cost of tuition.

Treatment

In this study students experienced two methods of teaching: direct teach and the 5E Instructional Model over the course of a trimester as outlined in Table 3. In the direct teach method, information was shared with students in a presentation form such as a PowerPoint or notes written on the white board. Throughout the presentation, students were given guided opportunities to practice what they had learned and independent practice to demonstrate their understanding. The learning progression in this method of teaching involves the teacher explaining the concept, and then students practicing what they have learned. For example, in the air pollution unit students were taught each day through a PowerPoint presentation followed by group practice problems and then independent assignments. After viewing a presentation on topic, such as smog and the

nitrogen cycle, students were tasked with organizing the information they had learned and then demonstrating their understanding of the main facts on homework assignments and a short project. The unit concludes with a quiz.

Table 3
Method of Instruction

Week	Instructional Method	Topic
1-2	Direct Instruction	Air Pollution
3-4	5E Guided Inquiry	Soils
5-6	5E Guided Inquiry	Carbon Cycle
7-8	Direct Instruction	Nitrogen Cycle

The direct teach method contrasts with the 5E Instructional Model of teaching in which students build their understanding from what is observed before the teacher shares the proper terminology to explain the phenomena they have seen. In the engage phase, the teacher generates curiosity in a natural phenomenon or issue. In my classroom I used a combination of raising questions through misconception probes and giving demonstrations. In the explore phase I allowed students to develop their understanding by observing a phenomena and testing their ideas. Throughout the explore phase I allowed students to collaborate on a problem or task without sharing the reason for the outcomes. In the explain phase, I encouraged students to develop their ideas and provide evidence for what they observed. In this part of the lesson I helped students develop their own understanding of the issue or concept by teaching the accurate terminology and information they would need to understand for a future assessment. In the elaborate phase I challenged students to apply what they had learned to new situations and better understand the concepts by using the appropriate terminology for what they had observed and in the explanations they had formed. The last step of the 5E Instructional Model is

evaluation. In this stage of the learning progression students were assessed on their ability to understand what they had learned and apply it to a new situation. For example, when students learned about the process of combustion in the carbon cycle unit we began the lesson by observing a lit candle and then describing the observed phenomena. Students then were given a glass jar to place within the flame and to determine why a black coating formed upon the jar. This activity allowed the students to engage with the idea of combustion and develop their own personal understanding of what they believed happened to the matter within the candle as it burned. In the explore phase, students were given the opportunity to test to see what happened to other materials, such as wood, when they were burned. Students formed conclusions based on their observations and were given opportunities to collaborate with each other to develop their ideas in both a sketch and written explanation. In the explain phase, I used a whiteboard to draw a sketch of the candle and notes to describe the way combustions works. At this point I used questioning to help students better understand how the process works and addressed any lingering misconceptions of students. In the explain phase students had to go back to their first observations and write an explanation of what happened and correct any misconceptions. In the final phase, students had to elaborate on what they had learned through an independent homework assignment which required them to connect what they had learned about combustion to the earlier unit on air pollution. The evaluation phase had two parts: a formative and summative assessment. Students completed a misconception probe and then this information was included within a quiz at the end of

the unit. A comparison of the direct teach and 5E Inquiry Instruction methods can be seen in Table 4.

Table 4
Examples of Direct Teach and Inquiry-Based Instruction

Direct Teach	Smog	5E Inquiry Instruction	Combustion
Anticipatory Set	Current Events: Smog in Beijing	Engage	Misconception Probe
Lesson Instruction	Smog Presentation	Explore	Observation of Candle: What happens to the mass of a candle when it burns? Why?
Guided Practice	Demonstration on Thermal Inversions 4 Step Model Outline (Structure, Changes, Drivers, Inquiry)	Explain	Whiteboard Explanation Students circle back to previous observations and write an explanation of what they observed
Independent Practice	Short Answer Questions on Smog	Elaborate	What happens to other materials when they burn? Air Pollution and Combustion Questions
Evaluation	Smog and Human Health Collaborative Project Quiz	Evaluate	Misconception Probe Quiz

Instrumentation

To study the effect of the 5E Instructional Model on student learning, engagement, and ability to transfer knowledge, pre- and post-assessments, surveys, interviews, and observations were used as seen in Table 5. Students were given pre- and post-assessments for each unit to compare the gains they had made throughout the treatment. The pre- and post-tests were composed of five short answer questions, which were evaluated for accuracy. These data were compared to determine if students

experienced a greater level of understanding in the treatment. Each unit contained a formative assessment to measure student progress including misconception probes, a tally sheet for engagement, a peer observation, and a reflective journal entry. Student surveys and recognition scores were collected before the treatment and upon its conclusion and interviews were conducted at the end once students experienced both direct teach and 5E Instructional Method.

Table 5
Data Collection Matrix

Research Questions	Data Source		
	1	2	3
How does the use of the 5E instructional model influence the ability of students apply scientific knowledge to new situations?	Pre/Post Assessment	Interviews	Formative Assessment
What affect does the 5E instructional model have on student engagement in and attitude toward science?	Student Surveys and Recognition Scores	Interviews	Tally Sheet for Engagement
How will a student-centered approach, using the 5E instructional model change my role as a teacher within the classroom?	Student Surveys and Interviews	Reflective Journal	Peer Observations

Interviews were to understand the student experience of learning using the 5E Instructional Model. Six students were randomly selected for interviews in this project, with two students representing each of the three levels: foundational, standard, and accelerated. The questions prepared for the interview centered on how students feel they learn best and the types of activities in my curriculum that were valuable for their understanding. The interview questions can be seen in Appendix B.

Students were observed for engagement in several ways: recognition scores and a tally and observations from the Science Department Chair, Tom Owen. Students were observed for the number of engaged behaviors they demonstrated through a tally sheet (Appendix C). Engaged behaviors include: focusing on the task by asking questions or sharing ideas about the topic assigned and showing active and passive listening skills. Students were also evaluated on their engagement through the Recognition System developed by Brewster Academy for evaluation of ten categories, one of which is engagement (Appendix D). Student surveys were utilized to get written feedback from students regarding their own assessment of their engagement in the class and to better understand their experience learning through the two instructional models (Appendix E).

I wrote journal entries once per unit to capture my observations and impressions of the lesson plan created and to track how well I felt the lesson engaged students and helped them move toward learning goals. Strengths and weaknesses of each lesson were recorded at the end of each unit. The journal template can be seen in Appendix F.

Peer observations were used to get an outside perspective of the lessons created for both the treatment and non-treatment aspects of this project. Once per unit the Head of the Science Department observed one of the lessons created to record details regarding student engagement, ability to meet learning goals, and the quality of the lesson being taught. The format of this observation can be seen in Appendix G.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. See Appendix H for IRB exemption and permission from

Brewster Academy's Head of School, Craig Gemmell. A timeline for this project can be seen in Appendix I.

DATA AND ANALYSIS

Students experienced two models of teaching methods throughout the year. Based upon the data collected students showed a slight increase in ability to use scientific concepts and engage in learning using the inquiry based methods of instruction. The use of this method also improved my skills as a teacher in reaching students in all levels, especially those in the lowest level of the curriculum. As a teacher, the incorporation of the 5E instructional model provided another tool to create meaningful lessons for students.

Student Ability to Understand and Use Scientific Concepts

In student ranking of lesson effectiveness on surveys, there were slightly higher average scores for lessons incorporating inquiry-based methods of instruction as seen in Figure 1. In this ranking students used a five-point rank, with low scores indicating low effectiveness of lessons and high score indicating high effectiveness. The ranked lessons were averaged to show the results in the figures. Students felt inquiry-based instructional lessons were more effective than those using direct teach. In comments students shared that they felt lessons were more effective when they were able recall the information and when they felt more engaged in the class experience. In the 5E instructional lessons students began the lesson with an activity and this allowed for greater participation from the beginning in contrast to the direct teach where students were given an activity later in the learning progression.

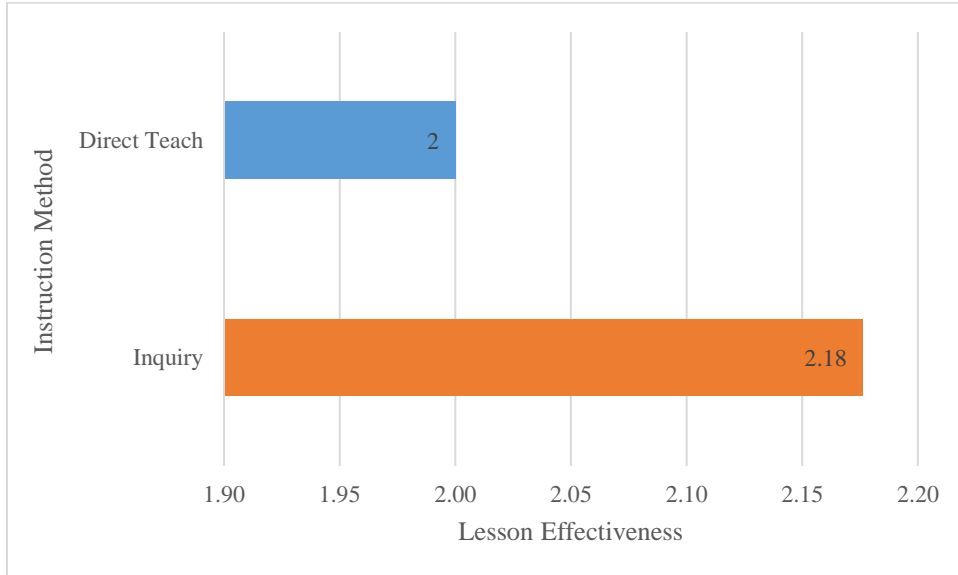


Figure 1. Student ranked effectiveness of lessons, ($N=48$).

The greatest increases in student assessed lesson effectiveness were for students at the foundational and standard levels, however all levels perceived greater lesson effectiveness when using inquiry-based methods of instruction when ranking lessons on a survey using a five-point scale, as seen in Figure 2. This demonstrates that all students felt inquiry-based lessons were more effective. Students working at the foundational level of the curriculum saw the greatest change in their perceived lesson effectiveness going from a score of 1.78 to 2.17 when ranking all the lessons taught in direct teach or inquiry-based format from most effective (5) to least effective (1). On average, students at the accelerated level who ranked effectiveness at 1.86 for direct teach effectiveness verses 2.04 for the inquiry-based instruction. One student writes, “The way the material is being given to us makes it sometimes easy and sometimes hard to understand. It really depends on what we are learning and how much information is being given.” Unfortunately, this student did not specify what learning methods worked best on the anonymous survey,

however I do think the time dedicated to each topic does influence the overall effectiveness of a lesson as well as the complexity of the issue being taught. Many students mentioned they learn best from hands on, collaborative, or visual learning. One student wrote they enjoyed “more hands on things because I like to see better than listening.” Another shares “I get distracted or bored easily, but usually we are in the lab doing something interesting. I think that there is a good balance between hands on and listening and taking notes in this class.”

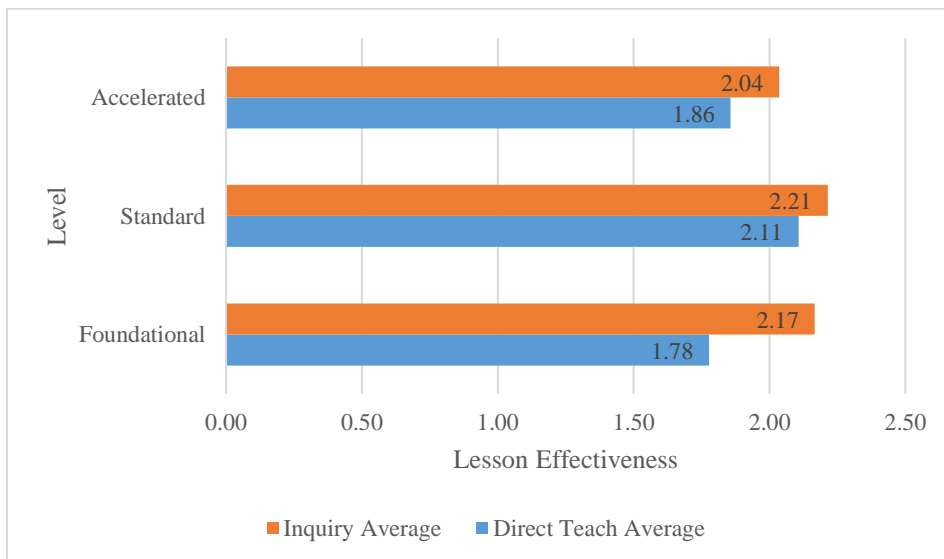


Figure 2. Student ranked effectiveness of lessons by student level, ($N=48$).

The 5E Instructional Model and the ability of students to apply knowledge showed slight differences from the direct teach model of instruction in regards to student performance on formal assessments. In the pre and posttests students made gains after both the direct teach and 5E inquiry method of instruction with a slightly higher average improvement for students after the inquiry based instruction as seen in Figure 3.

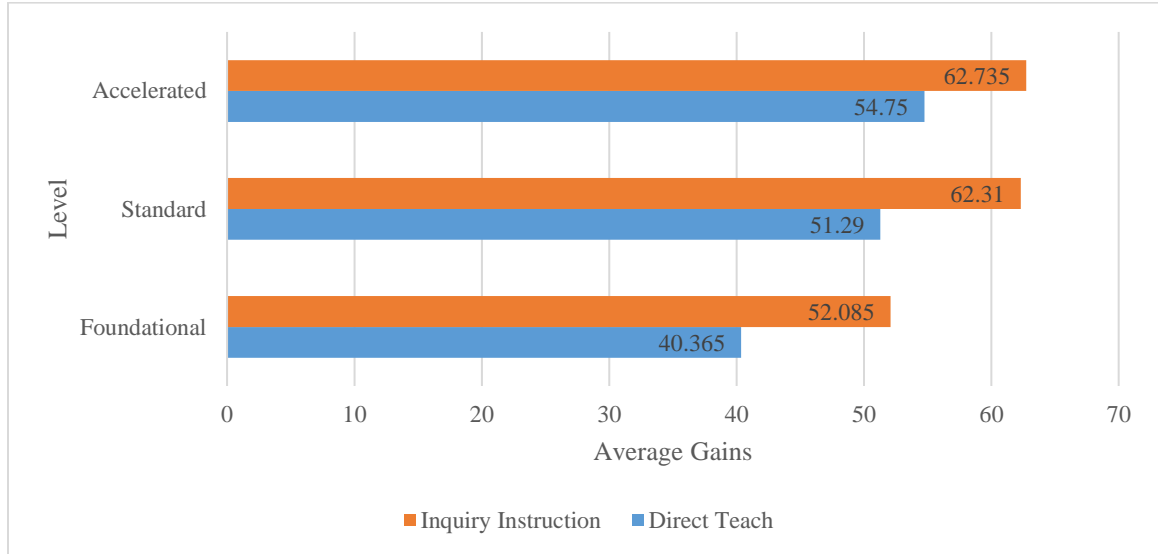


Figure 3. Pre and post-test gains, (N=48).

For both types of instruction, the greatest gains were shown by students working at the standard and foundational level, while accelerated students performed well regardless of the method of instruction as seen in Figure 4. Students in the foundational level showed a gain of 11.72 points after the inquiry-based unit in comparison to the direct teach unit. Accelerated students performed well with both methods of instruction, but showed a slightly greater gain of 7.985 points after inquiry-based instruction. Statistically significant gains were made by students at the foundational level in inquiry-based lessons versus direct teach lessons ($t=1.34$, $p<.1$, $df=12$). Students at the standard showed a moderate, but not statistically significant ($t=1.24$, $p>.1$, $df=31$) improvement in understanding when using inquiry-based methods. Students at the accelerated level showed a slight positive difference using inquiry-based lessons, with a p value of .1168, but this difference was not significant.

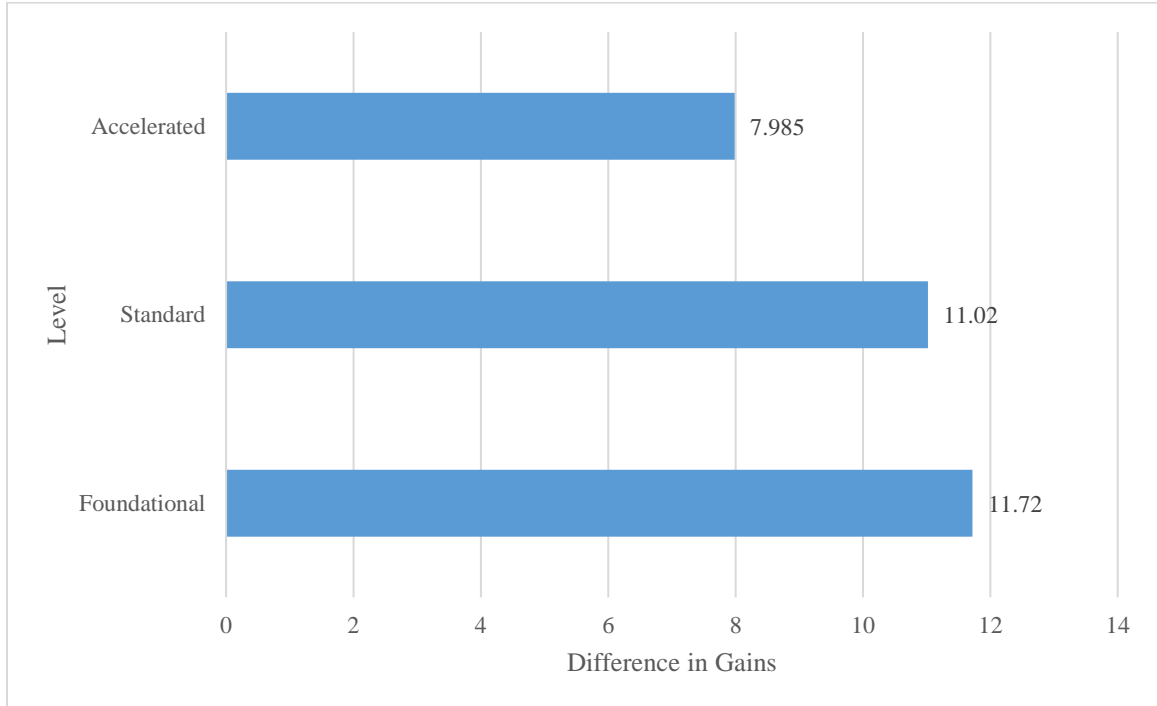


Figure 4. Difference in gains between inquiry based methods and direct teach by level, (N=48).

In my own observations of the lesson effectiveness I felt students showed a greater depth of understanding when utilizing inquiry methods, however part of this improvement may have been due to my own excitement of utilizing the 5E method of instruction, which may have resulted in slightly more emphasis on this topic. Both methods of instruction seem to be effective teaching tools, although I noticed an increase in the amount of time I took to work through the 5E instructional method. The direct teach lessons were accomplished in a shorter time. Two lessons were extremely well-planned and executed including the air pollution direct teach and the carbon cycle 5E inquiry lesson. Two lessons could use some more revisions including the soils 5E inquiry lesson, which needed more opportunities for students to review in the elaboration phase and the nitrogen cycle lesson, which occurred at the end of the trimester when students

were feeling the stress of upcoming exams and remaining teaching time was scarce. Luckily the nitrogen cycle fit into the last week of the curriculum, however this timing may have influenced my overall results. In my Department Head's observation of the carbon cycle 5E inquiry lesson he noted "circling back to the original scenario to demonstrate conceptual change" was an effective way to reach many students because it allowed them the freedom to alter their response based upon what they had learned and provided a safe space for students to be incorrect in their initial explanations of a phenomenon. In the air pollution unit, he noted the effectiveness of using a structure for students to organize their notes, however he wondered whether students were conflicted about paying attention to what I was saying versus determining what was important to include when writing notes. In the formative assessments students showed growth in their learning with the direct teach method, however the depth of their knowledge was limited recited facts versus the deeper understanding they were able to demonstrate on the inquiry-based formative assessments.

Student Attitudes and Engagement toward Learning

Student attitudes toward learning were similar with each teaching method in their surveys throughout the year, however their comments suggested a hands-on approach captured their attention more than any activity requiring lecturing and note-taking. One student wrote, "I feel she is strong in the lab and great at teaching us...but when it comes to giving PowerPoints she tends to lose me." Another shares this sentiment saying, "In science, there is a lot of note taking...so I can get distracted easily. But also we do things in the lab and I can stay involved." Tom Owen, the Science Department Head at Brewster

Academy, noted similar trends in his observations of student engagement during a Direct Teach and 5E Inquiry-based lesson during each five-minute increment of the fifty-five minute class period. In the lesson based upon the direct teach method of instruction, students seemed to be most engaged when actively doing a task or in their observations of a demonstration. While students did show engagement during note-taking, less was shown during times when the teacher taught using a presentation or led a discussion as seen in Figure 5. Mixed student engagement resulted from a collaborative activity initially, however once given time to determine individual tasks for each group member, every group showed full engagement at the conclusion of the class.

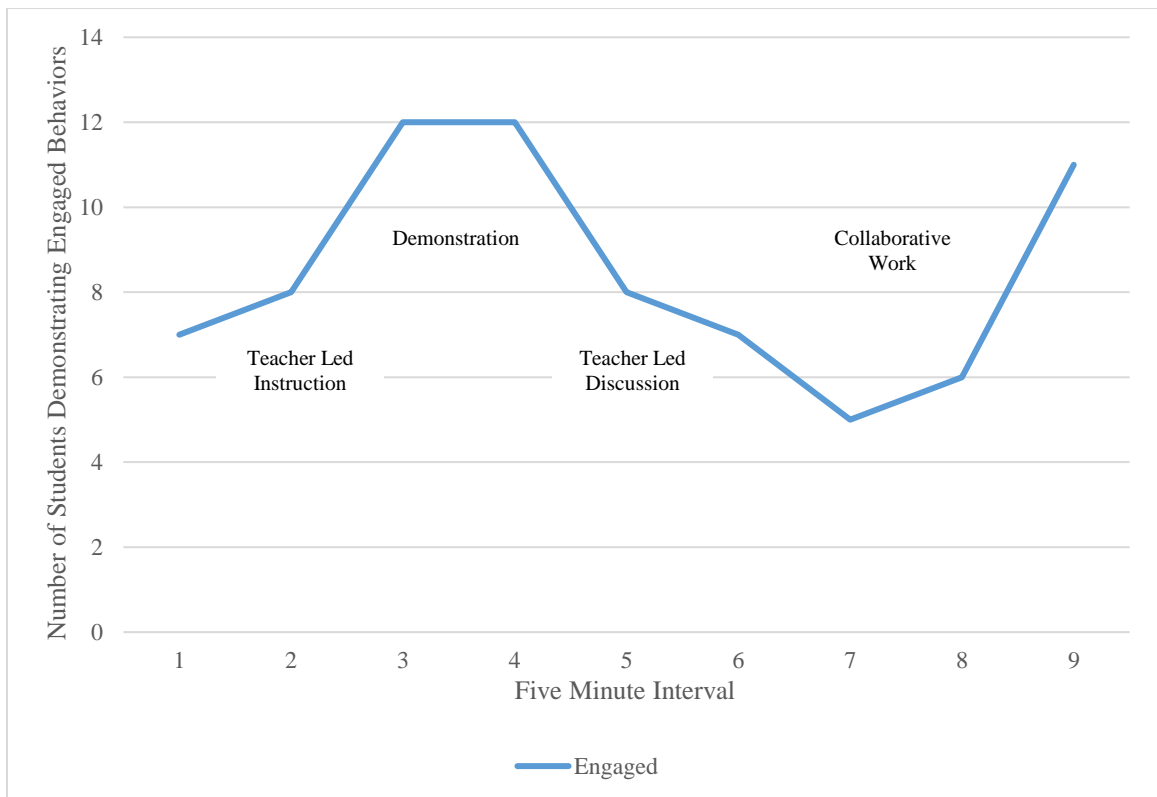


Figure 5: Student engagement tally during direct teach lesson, (N=12).

In contrast, students appeared to sustain attention longer during the lesson using the 5E inquiry method of instruction, which required students to take an active role in understanding the topic of soil. In my own observations of this lesson I found that my role shifted from being at the center of the class to facilitating groups in answering the questions posed to them. Throughout the period I rotated from one group to another and guided them in their understanding through asking questions and giving them opportunities to explain reasoning. While the 5E lesson also included a period of explanation, this differed from the direct teach experience in that students were prompted to provide their explanations and I confirmed when they were right by providing a deeper explanation of the concept they learned. Likewise, I corrected their responses to ensure all understood the concepts when they shared a misconception. This led to a higher involvement by students throughout the class.

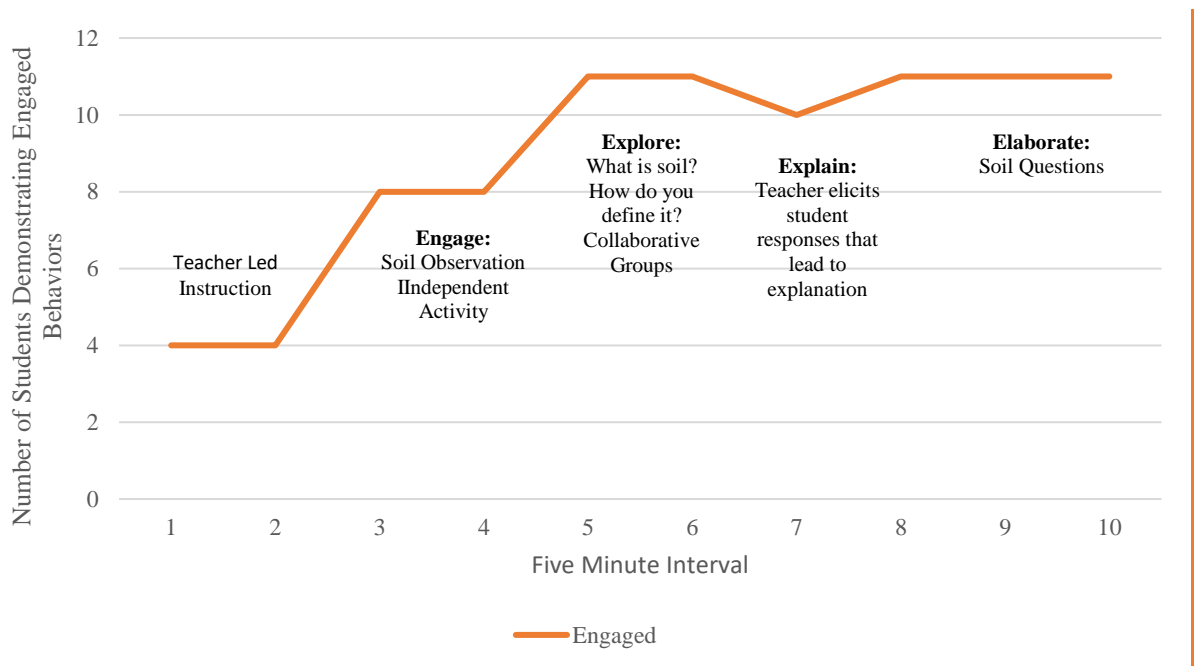


Figure 6: Student engagement tally during 5E inquiry-based lesson, ($N=11$).

Another common thread in student comments were the importance of collaboration to engage in learning. When asked why some units seemed to work better than others, students shared that interest in the topic and collaborative activities helped increase engagement. One student wrote, “some units entailed more collaboration, which is easier to engage in than notetaking.” Another writes the effectiveness of units in engaging students varied “because I had some background knowledge before or I was interested in that [topic].” When asked what should be changed in the class many students wrote that they would appreciate less homework and less time spent note-taking. However one student wrote, “...there are times where I find myself lost in the lesson simply because there are a lot of components. There are times where the plan for the lesson could be simplified.” While there needs to be enough in the lesson to keep students active and engaged, I do recognize there are times when allowing for greater processing time and reducing the amount of activities can be helpful; ideally I would like to find a balance between these two ideas within my classroom.

In a survey administered to three classrooms of ninth grade students (28 students) many students shared how previous experiences and attitudes toward science influenced their engagement as well as their perceived learning style. Each student was given the opportunity to complete this survey during class time anonymously and the format of the questions was open ended to allow students to elaborate on the reasoning for their responses. Most students (71% of 28) reported that they felt that a kinesthetic learning environment was beneficial to their growth as students. The skills most frequently

referenced in the responses were observation skills and making inferences as seen in Appendix J.

Twenty-one (84%) of my students reported enjoying science class, while seven (26%) students shared that they did not. Students felt strongly that science is interactive (46%). Nine students (32%) noted that the course covered topics of interest, while eight (29%) shared they enjoyed the collaborative approach of science. Almost all students (79%) described their role within the classroom as learners, however a few students found it difficult to define their role.

Student engagement in science class was self-reported as being greater during activities in which students were working on projects, conducting lab activities, group work, or independent work. Several students reported high levels during observation activities while others mentioned high levels of engagement during lab activities and projects. One student writes, “Environmental science has always been a class where things get done. Everyday there is always something to do to keep you busy which I love.” What is telling from these data is that no students mentioned lecture as a time of engaged behavior. Many students reported a lack of connection during specific times when paired with a student they did not enjoy working with or times when the teacher was explaining a project. Several students felt a lack of engagement when the class moved at a pace beyond their comfort level.

In the survey most students reported that they enjoyed science class, while a few shared that they did not enjoy science. One student wrote, “I enjoy science class this year and much more than I have in past years.” A possible reason could be the subject matter

and the hands-on opportunities, which have been our focus this year. There have been many collaborative opportunities and a major theme of the class has been using the information we learn to problem solve. One student wrote, “I like this class because we actually learn things and put them to use instead of just learning things and taking tests.”

Students value both the experience of hands-on learning and the opportunities cooperation and collaboration in a group brings. Four of the seven students who did not enjoy science in the fall traced their dislike back to a past science teacher, while two students felt the curriculum was too challenging. One student did not feel connected to me as a teacher and disliked my teaching approach.

Students showed a strong preference for kinesthetic learning, a learning style in which students engage in activities requiring physical movement (71%). This does not surprise me as approximately 30% of the students who took the survey were diagnosed with ADHD. In my evaluation of student recognition scores in the category of Active Engagement, the class on average showed slightly higher scores as seen in Figure 7. However, these scores cannot be directly correlated to inquiry-based learning as students typically show growth as they gain more experience throughout the year and scores may merely reflect this trend.

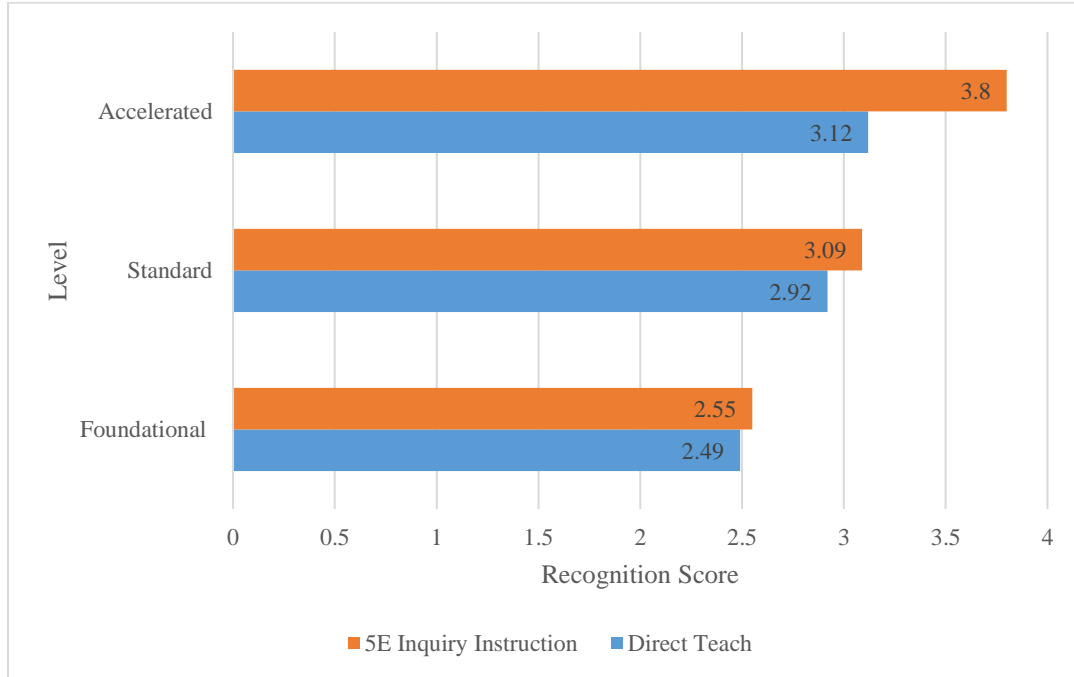


Figure 7: Recognition scores for engagement during direct teach and inquiry-based instruction, (N=48).

Teacher Growth

Students recognized the role of a teacher as being someone to teach a concept or skill (79%), however providing a safe and comfortable learning environment was also crucial from the student perspective. Students wanted a positive connection with their teacher and this greatly influenced their enjoyment of the class. Students also looked to teachers as role models. The feedback from students in terms of improvements in the class ranged from more time to review homework in class to more lab time and in the same survey administered later in the year this feedback stayed consistent. A few students suggested slowing the pace of the class, however no students mentioned this within the second survey. Students shared that the role of a teacher is “to teach the students a concept and to make sure their students are confident and comfortable.” Another student

said, “[The] role of a teacher is to give you skills that you can apply to the future such as like note-taking or observations. A perfect teacher would be someone who helps the students learn and is excited about what they teach.”

As I moved through the process of this project I realized that my goals as a teacher have shifted over time. While there is still a place for the teacher at the front of the classroom, I am most comfortable being a guide to student learning and I love having the opportunity to give students opportunities to learn skills that can carry them through their science experience. In my journal observations I noted during one of the direct teach lessons that there was “not much time to get the students up and walking around ‘doing’ science.” Likewise, the longer I spoke in front of students in a presentation the more difficult it became to sustain their attention. This was true regardless of the teaching model utilized. Generally, 15 minutes seemed to be the ideal time to do the explain phase of the 5E instructional model or the presentation phase of the direct teach. The creation of the 5E instructional model lessons took significant time to organize and this preplanning became crucial for me as I have less experience with this method of teaching. Even with this planning there were a lot more “on my toes” moments where I had to adjust my questioning to help student arrive the correct conclusion. While this can be difficult, I found I loved the challenge it provided as well as the opportunity for individualized instruction. Likewise, it allowed students of all levels to find a challenge. A much greater amount of time was spent by students in the 5E instructional model using the science skills of observation, questioning, and deriving conclusions based on evidence. The 5E instructional model fit well with collaboration, a major emphasis at my school. As a

teacher the 5E instructional model seemed to put students at the center of their learning and allowed me to grow in my ability to reach students especially at the lower levels of the curriculum.

INTERPRETATION AND CONCLUSION

In my classroom students found it challenging to apply the concepts they learned to new situations. I feared that many students memorized answers only to find they did not truly understand the meaning behind what they learned when faced with a new context. In traditional forms of teaching, much of the lesson time required the teacher to share their understanding with a class, followed by students practicing the skill taught. While this teaching method certainly has its advantages, it is crucial to give students opportunities to develop their own understanding by questioning what they believe to be true and developing explanations. While the use of direct teach certainly has its place within the classroom and can be an effective way of sharing information, students showed greater gains through the 5E instructional method and I found myself to be a more effective teacher using this style of teaching.

In the 5E instructional method, more freedom was given to students to engage in their learning experience as they became central to the process of conceptual change. In my classroom, I noticed student engagement waxed and waned with the amount of time I spend in front of the class; in times when students were given the freedom to collaborate and do science, they tended to be more engaged. One student shared “[The] classroom is very interactive and engaging,” while another wrote, “The parts that helps me most [in learning] is when we go into the lab. Hands on learning works best for me.” In lessons

using the 5E instructional model, students were given greater opportunities to be involved in their learning and when I used this practice within my classroom it resulted in greater investment from my students in their learning. More students showed consistent engaged throughout the class period during the observations of my Department Head. It also transformed my role as a teacher; instead of only being a source of information, I became a guide, who could lead students through the process of knowledge and reframing their ideas to develop a model of how the world works. However, part of the success of students may not be dependent on one particular teaching style, but in giving opportunities for students to experience many different instructional models. One student noted, “She tries new teaching styles and mixes up the class a bit, from presentations to labs.” In the 5E instructional method I felt the focus of my class shifted away from me allowing for more opportunities for students to engage with the class and learn concepts. Students at all levels performed better when experiencing the 5E instructional method. Likewise, I enjoyed my role more as a facilitator of learning and I felt better able to reach students at the lower levels of my class. Students at the higher levels benefitted as well as it allowed for a greater depth of understanding and the misconception probes gave opportunities for students to share their ideas without the fear of being wrong.

While both methods of instruction have their strengths, I believe a combination of these methods will best serve students in their learning. I believe there are skills associated with each of these methods that prepare students for success and I think multiple instructional approaches gives students a way to continually engage with the

class. While routines and repetition are crucial, there is also a place for change in the classroom and having multiple tools to draw upon can elicit student engagement.

In response to my questions on student engagement students found the inquiry-based lessons more engaging than the direct teach lessons due to the interactive and hands-on opportunities they provided. The observations of my Department Head and my own journal entries reflected this as well. In terms of the ability of students to understand and apply scientific concepts, there were advantages to using the inquiry methods especially for students at the lower levels of the curriculum. While accelerated students showed minor benefits, both direct teach and inquiry-based teaching can provide opportunities for these students to find success. This was seen in the pre-test and post-test data as well as in the formative assessments used. Likewise, students felt more confident with what they had learned when using the inquiry-based model. As a teacher I felt that inquiry-based teaching allowed me greater freedom to help guide students in their learning process. While the direct teach method has its place in the toolkit of teachers, inquiry-based learning offers a great opportunity to support students needing the most help in understanding the curriculum.

VALUE

Inquiry within the science classroom hinges on the idea that questions guide the learning process (Llewellyn, 2008). At the heart of inquiry is the idea that learning is best accomplished through developing authentic and meaningful questions to study and subsequent investigations. In developing conclusions based upon evidence we learn to revise our thinking to incorporate newly formed ideas. As we move through the cyclical

process of testing our ideas, new questions develop and our experience, observation, and inferences drive our ability to construct new mental models of how the world works. However, the quality of each question matters; a well-defined purpose is paramount. Through this process I hypothesized that students would be better equipped to apply concepts they had learned after using the 5E instructional model and I hoped that this would build self-confidence and independence as they understood how to learn from their misconceptions and develop understanding. In my classroom this project allowed me to better understand the effects of inquiry instruction upon both my students and my own development as a teacher.

Investigating the use of inquiry based learning, using the 5E instructional model, helped me create a classroom culture that embraced questioning and permitted students to work through previously held misconceptions; it allowed students to experience failure and learn from their mistakes, a skill that holds significance not only in science, but far beyond. Inquiry provides a relevant and valuable tool for giving students the opportunity to develop questioning skills; by asking thoughtful questions, observing phenomena, and then relating it to their knowledge of the world, they will better understand how the world works and develop the critical thinking skills necessary to make decisions and analyze problems. The benefits of this experience helped my students, my school community, and helped me in developing my ability as a teacher to best serve my students in providing a meaningful educational experience that prepares them for the real world.

As I move into my tenth year of teaching I hope to create a learning experience that incorporates the philosophy of inquiry-based methods into my classroom on a more

frequent basis and I hope to utilize the conceptual change model as an integral piece of student learning. I would like to explore how reflective feedback can be incorporated into this process of learning and how to best utilize the student science notebooks as a space to track conceptual change and provide opportunities for student metacognition.

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APPENDICES

APPENDIX A
STUDENT PLACEMENT CRITERIA

Criteria	Foundational 1	Standard 2	Accelerated 3
Score on IOWA or most recent exam	Below 60	60-80	80-100
Class Groupings Assessment (Overall Performance in the first 2-3 weeks)	Below 2	2-3	Higher than 3
Current Overall Grade	0-79	80-94	95-100
Current Homework Grade	0-89	90-94	95-100
Last Test Grade	0-79	80-94	95-100
Math Course (Initial Placement Only)	Algebra 1	Geometry Algebra 2	Precalculus
AVERAGE	0-1.8	1.9-2.5	2.6-3

APPENDIX B
INTERVIEW QUESTIONS

- 1) Do you enjoy science class? Explain why or why not? Have you always enjoyed science class? (or not enjoyed).
- 2) What is the role of a teacher within a classroom? Why do you think that? What would a perfect teacher look like in your viewpoint?
- 3) What is the role of a student within a classroom? Why would you think that?
- 4) How do you learn best? What type of learning environment do you feel best serves students? Why do you think that?
- 5) Describe a time when you have felt fully engaged in this class.
- 6) Describe a moment when you did not feel connected to the class.
- 7) Give an example of an activity you feel has been helpful in your learning in this unit.
- 8) What skills do you think you have gained from this class?
- 9) Do you prefer direct instruction or inquiry based learning? Explain why. Have you had teachers in the past who used both of those and what was that like?
- 10) If you could change one part of this class, what would it be? Why?

APPENDIX C
TALLY FOR ENGAGEMENT

Name	Write in number of students displaying engaged behaviors in class at 5 Minute Intervals									
	5	10	15	20	25	30	35	40	45	50
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										

Behavior Codes

T=On Task

- Writing
- Raising hand
- Reading aloud
- Answering questions
- Talking concerning academics
- Flipping through pages of book
- Reading silently
- Listening to teacher
- Listening to peers
- Looking at whiteboard for technical instruction
- Looking at Academic Materials

O=Off Task

- Any motor activity not related to the task
- Any bending or reaching
- Motor contact that is not academic
- Flipping through pages of non-academic material
- Drawing/writing that is not permitted
- Manipulating objects not academically related
- Talking to others unrelated to academic situation
- Inappropriate laughing
- Audible sound not academically related
- Sitting quietly in unassigned activity
- Staring out of the window or into space

APPENDIX D

BREWSTER ACADEMY RECOGNITION SCORE ITEMS

Recognition Items	1 Does not meet expectation	2 Completes expectation with teacher support	3 Meets Expectation independently	4 Expectation a habit of mind
1. Respect				
2. Positive Attitude that Reflects Managing Emotions				
3. Cooperation and Collaboration				
4. Actively Engaged				
5. Advocates responsibly that Reflects Best Self				
6. Student Models Appropriate Behavior that Reflects Best Self				
7. Completes Assignments with Integrity				
8. Dresses Appropriately				
9. On Time				
10. Prepared for Class				

APPENDIX E
STUDENT SURVEY

Classroom Practices	1 Never	2 Sometimes	3 Mostly	4 Always
1. My teacher uses teaching methods and materials that help me learn				
2. My teacher is knowledgeable about the subject matter				
3. My teacher explains things clearly in a way that I understand				
4. My teacher sets realistic, yet high, expectations for me				
5. My teacher provides me with appropriate opportunities to practice what has been taught				
6. My teacher provides enough opportunities to participate in each lesson				
7. My teacher provides me with frequent opportunities to participate in each lesson				
8. My teacher makes homework assignments clear to me				
9. My teacher prepares me to do my homework successfully				
10. My teacher gives me feedback in a timely fashion				
11. My teacher makes grading criteria clear to me				
12. My teacher helps me understand why I am placed in my instructional groupings				
13. My teacher helps me understand how I can advance my instructional grouping				
14. My teacher makes it clear what I need to do in a module of study				
15. My teacher is concerned about my growth and success				

Classroom Environment	1 Never	2 Sometimes	3 Mostly	4 Always
1. My teacher manages behavior in the classroom effectively				
2. My teacher creates a positive learning environment				
3. My teacher creates an interesting learning environment				
4. My teacher makes class rules clear to me				
5. My teacher enforces rules fairly				
6. My teacher frequently shows me how my behavior translates into Recognition scores				
7. My teacher communicates well with me				

APPENDIX F
JOURNAL REFLECTION TEMPLATE

Date	Lesson Description	Notes
Questions:	<ul style="list-style-type: none">• What is my role within this lesson?• How much instructional time was used for students to do science?• How much time did you spend on the lesson and on setting up the lesson?• What were the strengths and weaknesses of this lesson? Provide a reason for your viewpoint.• How engaged were students during the lesson? List two ways you know this.	

APPENDIX G
PEER OBSERVATION

Observational Narrative		
Classroom Atmosphere	Developing Exemplary	Satisfactory
Instructional Methods	Developing Exemplary	Satisfactory
Student Learning	Developing Exemplary	Satisfactory
What percentage of the class involved students “doing” science?		
What percentage of the class was the teacher giving instruction?		
Describe student engagement throughout the class. Give one specific example of a student demonstrating this behavior.		

APPENDIX H
IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
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 Montana State University
 Bozeman, MT 59718
 Telephone: 406-994-6783
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 Cheryl Johnson
 406-994-4706
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MEMORANDUM

TO: Michelle Dodge and Walt Woolbaugh
FROM: Mark Quinn *Mark Quinn*
DATE: November 29, 2016
SUBJECT: "The Influence of Guided Inquiry of Science Skills and Engagement within a 9th Grade Environmental Science Differentiated Classroom" [MD112916-EX]

The above research, described in your submission of November 29, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

MONTANA STATE UNIVERSITY
Request for Designation of Research as Exempt

Confirmation Date: 11/29/16 Mark J. Jc
Application Number:

DATE OF SUBMISSION:

I. INVESTIGATOR:

Name: Michelle Dodge
Address: Brewster Academy, 80 Academy Drive, Wolfeboro, NH 03894
Phone: 603-986-5703
E-mail: michelle_dodge@brewsteracademy.org
DATE TRAINING COMPLETED: February, 23rd, 2016

Investigator Signature: Michelle Dodge 11/18/2017

Name of Project Advisor: Walter Woolbaugh
E-mail Address: walter.woolbaugh@ecat.montana.edu

- ok as exempt
- MSSE Classroom assessment
- Little/no risk
- Principal approved
- No concerns

MJ
11/29/16

II. TITLE OF RESEARCH PROJECT: The Influence of Guided Inquiry on Science Skills and Engagement within a 9th Grade Environmental Science Differentiated Classroom

III. BRIEF DESCRIPTION OF RESEARCH METHODS: I will be comparing the 5E Inquiry Instructional Model to the Direct Teach Model within my classroom. I will collect data on whether it influences the ability of students to transfer knowledge in addition to its impact on student engagement within my Environmental Science class. I also want to explore how the 5E Instructional Model will change my role as a teacher within the classroom. Please see attached copies for data collection instruments.

IV. RISKS AND INCONVENIENCES TO SUBJECTS
There are no foreseen risks to participation in this research project.

V. SUBJECTS
a. Expected number of subjects: 51
b. Will research involve minors (age < 18 years)? YES

This research will be conducted in a classroom setting for 9th grade students with ages between 14 and 16 years old.

- c. Will this research involve prisoners? NO
- d. Will research involve any specific ethnic, racial, religious, etc. groups of people?
NO

VI. FOR RESEARCH INVOLVING SURVEYS OR QUESTIONNAIRES:

- a. Is information collected about:
 - Sexual behavior NO
 - Criminal behavior NO
 - Alcohol or substance abuse NO
 - Matters affecting employment NO
 - Matters relating to civil litigation NO
- b. Will the information obtained be completely anonymous, with no identifying information linked to the responding subjects? NO
- c. If identifying information will be linked to the responding subjects, how will subjects be identified?
 - By name NO
 - By code YES
 - By other identifying means NO
- d. Does this survey utilize a standardized and/or validated survey tool/questionnaire?
NO

VII. FOR RESEARCH BEING CONDUCTED IN A CLASSROOM SETTING INVOLVING NORMAL EDUCATIONAL PRACTICES

- a. This project has been approved by Dr. Craig Gemmell, Head of School at Brewster Academy. A copy of this approval has been included at the end of this document.
- b. Participation in this research by students is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.
- c. I am sending as a separate attachment the Exemption Administrator Sign Off Form.

Administrator Approval

I, Craig Gemmell, Head of School at Brewster Academy, verify that I approve of the classroom research conducted by Michelle Dodge.

CG
(Signature)

HEAD of School
(Title)

Craig Gemmell
(Printed Name)

11/28/16
(Date)

Exemption Regarding Informed Consent

I, Craig Gemmell, Head of School at Brewster Academy, verify that the classroom research conducted by Michelle Dodge is in accordance with established or commonly accepted educational settings involving normal educational practice. Participation by students in this research process is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Signature: CG

Printed Name: Craig Gemmell

Date: 11/18/16

APPENDIX I
TIMELINE OF ACTION RESEARCH PROJECT

Week	Nov.	Dec.	Jan.	Feb.	March	April	May	June
1	Formal permission from Head of School to conduct research	Air Pollution (DT) Interview Pre 1 Rec scores Tally Journal	Soils (5E) Interview Pre 2 Tally Journal	Carbon Cycle (5E) Observation Pre 3 Tally Journal	Nitrogen Cycle (DT) Observation Pre 4 Tally Journal	Write methodology section	Critical friends review paper	Draft sent to science reader
2	IRB Process	Air Pollution (DT) Observation Assessment Post 1 Survey Journal	Soils (5E) Observation Assessment Post 2 Survey Journal	Carbon Cycle (5E) Interview Assessment Post 3 Survey Journal	Nitrogen Cycle (DT) Interview Assessment	Write analysis section	Edits	Submit draft for revisions
3	NONE	NONE	Data organization (Air and Soils)	Data Organization (Carbon Cycle)	Data Analysis	1 st draft of paper completed	Edits	Practice Capstone Presentation Submit final draft of capstone paper
4	Finish literature review	NONE	Data organization (Air and Soils)	Data Organization (Carbon Cycle)	Data Analysis	Edits	Use feedback to finalize paper	Thank you cards to critical friends, advisor, and science reader

Pre= Pretest

Post=Post-test

Rec = student recognition scores

Interview = Student interview

Observation = Peer Observation

Journal = Reflective Journal

Tally= Tally sheet for engagement

Assessment = Formative Assessment

APPENDIX J

SURVEY QUESTION SUMMARY OF RESPONSES

Survey Sub-Category	Survey Question	Summary of Responses
Ability to comprehend and transfer knowledge	<p>How do you learn best? What type of learning environment do you feel best serves your needs?</p> <p>What skills have you gained from this class?</p>	<ul style="list-style-type: none"> • Kinesthetic learning (15) • Collaborative Work • Visual learning style • Observation skills • Making inferences • Graphing skills • Note-taking
Student attitudes toward science	<p>Do you enjoy science class? Explain why or why not?</p> <p>What is the role of a student within a classroom?</p>	<p>Yes (21)</p> <ul style="list-style-type: none"> • Interactive nature of science “doing things” (13) • Topic covered in class of interest (9) • Group work opportunities <p>No (7)</p> <ul style="list-style-type: none"> • Difficulty or disinterest in understanding curriculum • Past challenges in science (dislike of subject, teacher) • To learn (22) • Collaborate with others (8) • Keep an open mind • Don’t know
Student engagement in science class	<p>Describe a time when you have felt fully engaged in this class.</p> <p>Describe a moment when you did not feel connected to the class.</p> <p>Example of an activity that has been helpful to your learning.</p>	<ul style="list-style-type: none"> • Observation Skills (8) • Labs: Stream Study • Graphing • Projects • When pace of class is going faster than I can understand • Teacher explaining project • Group work with specific peers • Water quality testing labs • Graphing Activity • Collaborative group work
Role as a teacher	<p>What is the role of teacher within the classroom?</p> <p>If you could change one part of this class, what would it be?</p>	<ul style="list-style-type: none"> • To teach a concept or skill (22) • Provide a safe and comfortable learning environment • Role model • More lab time • More frequent review in class • Less writing, reading, and homework • Reduce pace of class

N=28