A REVIEW AND ANALYSIS OF MSSE CAPSTONE PAPERS TO DETERMINE THE IMPACT OF THE 5E LEARNING MODEL ON SECONDARY EDUCATION SCIENCE CLASSROOMS

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2023

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ABSTRACT

The purpose of this review was to investigate how the 5E Instructional Model impacts student performance, student engagement, and student interest in science within secondary science classrooms compared to traditional teaching methods. A review and analysis of Capstone papers from the past ten years from the MSSE program at Montana State University was completed to draw a conclusion. The Capstone papers were organized by focus questions, methodologies, and results to identify commonalities and differences within the research. It is suggested that even through various methodologies, class sizes, and class demographics, the 5E Model has a positive influence on student performance, student engagement, and student interest in science.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

School Demographics

I am currently teaching Honors Chemistry and AP Chemistry at East High School. East High school is one of the largest high schools in Denver, Colorado. East is a traditional public high school, consisting of 9th through 12th grade students. Many of the students here are between the ages of 14 and 18. This is a school that students desire to go to. For the 21 - 22 school year, 877 students were accepted into the school with a wait list of 167 students (Denver Public Schools School Finder, n.d.). Since so many students are accepted to East High School, the culture and diversity are rich and welcoming. As of the 2021-2022 school year, the student population is 2,579. Out of the 2,579 students, 52% are white, 16% are black, 21% are Hispanic, 3% are Asian, and 7% are two or more races (Denver Public Schools School Finder, n.d.). A large student population also requires a large staff. East has approximately 130 full time educators. There are a total of 18 science teachers who collectively teach 86 different sections, most of which do not have an open seat. We offer AP, honors, general, and inclusion science classes to support the wide skill set and abilities that these students possess.

Context of the Study

To address the issue of the American workers' lack of fundamental knowledge in science, engineering, and technology, *A Framework for K-12 Science Education* was introduced and serves as a foundation to the Next Generation Science Standards (National Research Council,

2012). The Next Generation Science Standards (NGSS) offers students and educators a three-dimensional approach that conveys the core ideas and practices around science and technology (National Research Council, 2012). Although the framework and standards were first introduced in 2011 by the National Research Council, Colorado did not adopt the Next Generation Science Standards until 2018.

In the 2018 - 2019 school year me and the other members of the chemistry team attempted to embrace these new standards. We introduced scientific phenomena, which are occurrences in the natural and human-made world that can be observed and cause one to wonder and ask questions. For example, one unit that we carried out was having students explore the Flint Water Crisis and answer the question, "How did lead get into Flint, Michigan's tap water?" This attempted to help students connect to their learning while also investigating real world chemistry problems through this three-dimensional approach (Science Resource Center, 2022). This phenomenon was very interesting to kids for the first few weeks. Unfortunately, most of the phenomena we introduced did not last a few weeks, instead lasting for months. After months of investigating and discussing the same phenomenon, student interest plummeted. In addition to the phenomena lasting too long, they were also unsolvable to a certain extent. Students did not have enough chemistry knowledge by the end of the unit to fully end the investigation.

This problem is analogous to building an airplane, while simultaneously trying to fly it. We continued to adapt the phenomena the next year to try and shorten the amount of time spent on each unit, but student engagement remained low and student performance declined. After completing the 2021 - 2022 school year, I believe it is more important than ever to get students to reconnect and engage with their learning. It is more important than ever for teachers to have

high performance expectations once again for students. And it's more important than ever to help students think again.

My colleagues and I are frustrated by not being able to create a strong lesson that aligns with NGSS. We are frustrated with students' inability to engage and perform well. We are frustrated by the increased number of students who are not interested in science. However, I have recently stumbled across the 5E Model of Instruction, and I am curious if it can help alleviate our frustrations.

Focus Statement

This review focused on addressing the following question, What is the impact of the 5E Model on secondary education classrooms?

My sub questions of this review include the following:

1. Does the 5E Model increase student performance?
2. Does the 5E Model increase student engagement?
3. Does the 5E Model increase students' interest in science?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Defining NGSS

The traditional teaching model is heavily centered around the teacher. The teacher does the majority of the talking, shows students how to solve a problem and then the students complete a practice problem on their own. This teaching method is centered around repetition and memorization while ignoring the need to develop essential skills such as critical thinking and problem solving (Green, 2021). It is argued that the youngest of students are capable of reasoning beyond lower order thinking skills (Vigeant, 2016). The most recent development to expose students to higher level thinking and address the teaching of science that includes best practices in science education are the Next Generation Science Standards.

Next Generation Science Standards are modeled from three individual dimensions that are of equal importance to science education. The first dimension is Disciplinary Core Ideas (DCIs). DCIs are fundamental ideas that cover the four domains of science: Physical Science, Life Science, Earth and Space Science, and Engineering. DCIs build on each other for students to naturally progress from year to year. The second dimension is the Science and Engineering Practices (SEPs). These practices emulate what a scientist does when they investigate the natural world or what an engineer does when they create, design or build. The eight Science and Engineering Practices are

1. Ask questions and define problems
2. Develop and using models

3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics or computational thinking
6. Construct explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating and communicating information

The third and final dimension are the Cross-Cutting Concepts (CCs). The different science topics are usually taught separately, but within the NGSS Frameworks they are all connected. The seven crosscutting concepts are designed to help students see the connections of the four different science domains and develop a clear, science-based view of the world (NGSS Lead States, 2013) (Figure 1).

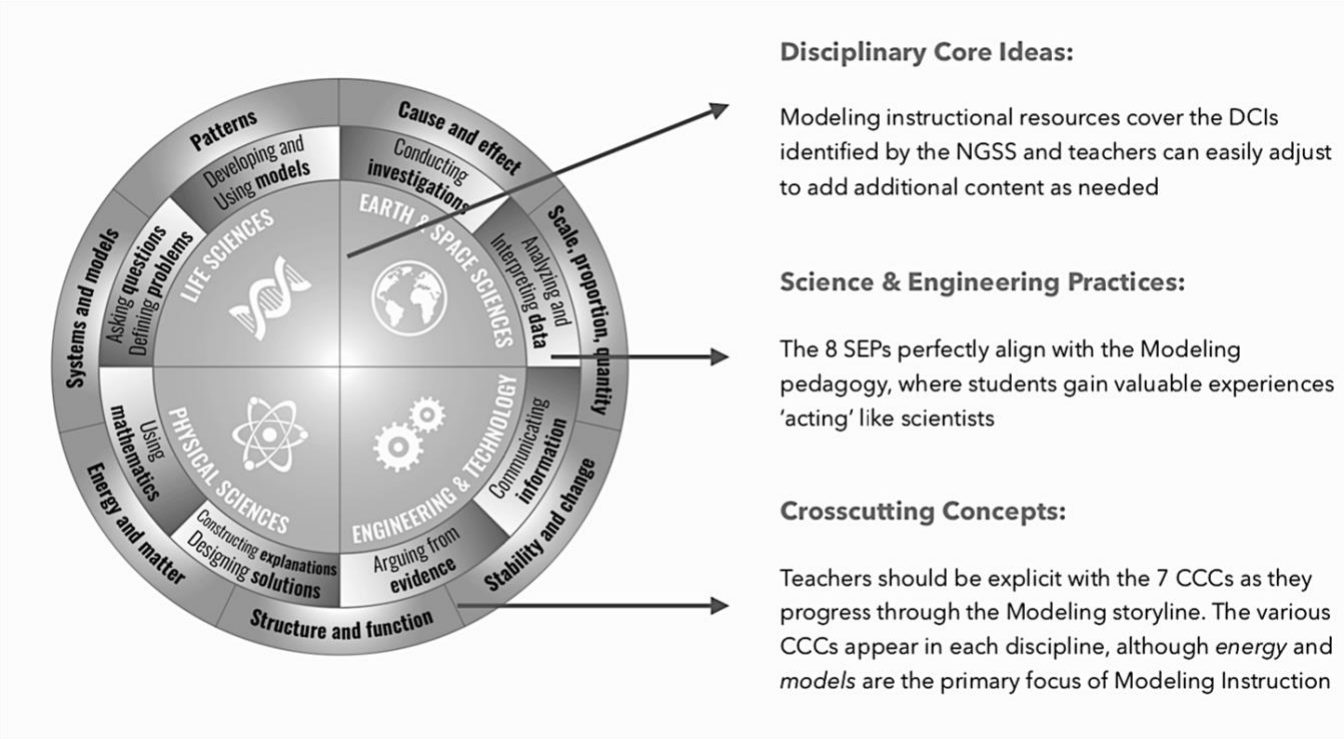


Figure 1. The Next Generation Model (American Modeling Teachers Association, 2019)

Defining the 5E Model

One way that students can be introduced to the Next Generation Science Standards is by the implementation of 5E Model. The 5E Model aims to help produce scientifically literate students, meaning students will develop an understanding of the methodology and the observations that take place to solve a problem. The standards that guide educators throughout the course of a school year is the "what." The "what" for science educators is NGSS. While the 5E Model helps educators construct the "how" (Chitman-Booker & Kopp, 2013). It is an adaptable method that can be used in any classroom. The 5E Model was created by Biological Science Curriculum Study (BSCS) but originated from the Learning Cycle developed by Atkin and Karplus in 1962 (Lesley University, n.d.). The Learning Cycle consisted of three steps: exploration, term introduction and concept application. The 5E Model is also a cycle but consists of five phases rather than three. The five phases of the 5E Model are engage, explore, explain elaborate, and evaluate (Figure 2).

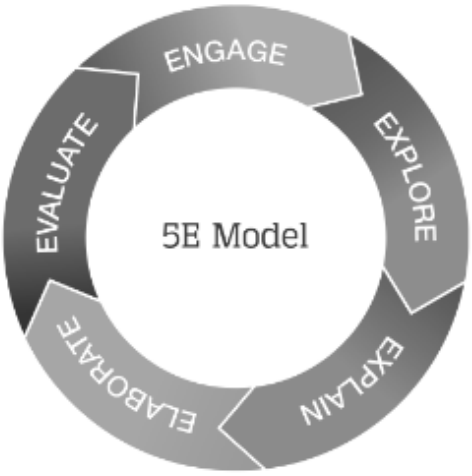


Figure 2. The 5E Model (McGraw Hill, n.d.)

The first phase of the cycle is engage. Much like the name suggests, this phase is designed to grab students' attention. The teacher presents a phenomenon to spark curiosity and generate questions. A wide range of phenomena could be presented. Some of the more common examples include demonstrations, a past or current event, a visual, or a video clip. These phenomena help expose a student's prior knowledge, but also expose gaps in their understanding. However, this should not be mistaken as a preassessment and there are two main points to this phase. The primary purpose of this phase is for students to become perplexed which naturally causes them to consider the content related to the learning outcomes. The second purpose of this phase is it allows educators the opportunity to informally identify misconceptions communicated by students (Bybee, 2014).

For example, in the Intermolecular Forces and Properties Unit in an AP Chemistry class, a demonstration called *Vanishing Styrofoam* can be done. This serves as the engage phase for the topic of dissolving. There are two aluminum cans; one can contains water and the other can contains acetone. Cubes of Styrofoam are dropped into the aluminum can containing water first. The cubes stack on top of one another, nothing happens. Then cubes of Styrofoam are dropped into the aluminum can containing acetone. The cubes seem to disappear in front of the students, but really, they are being dissolved (Figure 3). There is a limit to how many cubes dissolve, but the number is exceptionally high. Students are puzzled by what they observe. The overall objective is for students to explain what is happening inside the can containing acetone.



Figure 3. Screenshots from a video illustrate the progression of Styrofoam dissolving in acetone (Fix, 2012).

After the engagement takes place, students need time to investigate what they observed. The next phase is explore. This phase is where there is a major shift from the traditional teaching method to the 5E Model. More often than not, students are taught all the material about a topic up front and then conduct an experiment or hands-on activity to re-enforce their learning. This section of the 5E Model essentially reverses the order. Students conduct hands-on activities or experiments first (Harjo, 2021). During this phase students are fully immersed in the inquiry process. They are exploring the phenomenon to generate new questions or make sense of what they are observing. This phase allows for students to start at the same level of understanding. Each student will enter the classroom with their own experiences around certain events. Giving all students a chance to connect to an event is a powerful opportunity within the classroom (Llewllyn, 2007). While students are taking ownership of their own learning, the teacher is acting as a facilitator. During this phase the teacher will introduce the activity, provide any relevant background information and materials or address misconceptions (Bybee, 2014).

Continuing with the *Vanishing Styrofoam* demonstration, students explore their observations. The teacher could present students with different solvents in addition to water and acetone. Students can observe what solvents do or do not make the Styrofoam “disappear.” This can also be done by students watching videos of different substances interacting with the

Styrofoam, as some solvents are too dangerous to have in the classroom. Students will also be able to observe that the Styrofoam did not disappear, it just changed forms. The students are answering previous questions that were initially presented in the first phase while also generating new questions.

The third phase of the 5E Model is explain. In this phase the teacher is now more involved with direct instruction and draws students' attention to particular parts of the engagement and exploration phases (Bybee, 2009). The teacher should assist students in observing patterns, analyzing results, or forming conclusions from previous activities that took place during the earlier stages of the learning process. This is the opportunity for students to define any significant vocabulary and receive explicit instruction about the concept (Chitman-Booker & Kopp, 2013).

In the *Vanishing Styrofoam* demonstration, the class would look for patterns in what substances made the Styrofoam disappear and what substances did not. Students would also be presented with the molecular structure of each substance tested and conclude why some substances were able to interact with Styrofoam while others could not. This is also a perfect opportunity to redirect students to use discipline-specific terminology. Instead of stating that the Styrofoam disappeared, the class can now state that the Styrofoam dissolved, and define what it means when a substances dissolves.

Once students gain crucial knowledge about the phenomenon and any related concepts it is time for them to extend their thinking. This begins phase four, elaborate. Students connect with their peers and express their understanding of the topic. By sharing ideas, students can provide or receive feedback and clarification from others who are at their same level of

understanding (Bybee, 2009). During this phase, a new situation can also be presented to students. Students may struggle to transfer their knowledge to a different scenario. They often believe that what they previously learned about only applies to that specific scenario. By presenting a new scenario to students, it allows them to apply their thinking and make connections to other related concepts (Chitman-Booker & Kopp, 2013). By presenting students with new experiences, they can expand and strengthen their knowledge on a topic (Bybee, 2009).

Now that students are no longer questioning the *Vanishing Styrofoam* demonstration, they would be shown a new phenomenon. This should be related to the same topic. In this case, students can be asked about oil and water. Students can have a clear jar containing both water and oil. They can shake it up and over time, the oil will separate from the water. Why do they not mix? Students should be able to extend their thinking from the *Vanishing Styrofoam* demonstration to explain what they are observing.

As with any subject, once students reach the end of a unit it is time for them to demonstrate their understanding of the concept(s). The final phase of the 5E Model is evaluate. Throughout each of the phases, there are many chances for formative assessments to determine whether students are mastering the objectives; however, this phase is intended for summative assessment (Chitman-Booker & Kopp, 2013). The style of summative assessment given is up to the teacher, however the assessment should provide conclusive and decisive evidence of a student's understanding of a concept.

What students learned from the *Vanishing Styrofoam* demonstration is only a small fraction of the overall unit. However, students would be tested on the concept of dissolving. On the exam students would be asked to extend their thinking even further to demonstrate that they

truly understand the concept. In this situation, students could be asked about soap. Soap interacts with both water and oil even though oil does not dissolve in water. Students would explain how the structure of soap allows it to interact with both oil and water.

As mentioned earlier, there are countless opportunities for formative assessments to be given. Depending on the results of these formative assessments, the teacher may need to adjust their teaching. Although the 5E Model is a cycle, it is not a one-way street. The teacher can cycle back to any phase when the results of the assessments suggest that the teacher does so (Figure 4). For example, if students were not able to extend their thinking from the *Vanishing Styrofoam* demonstration to oil and water not mixing, the teacher would need to go back to the explain phase before proceeding to the elaborate or evaluate phases.

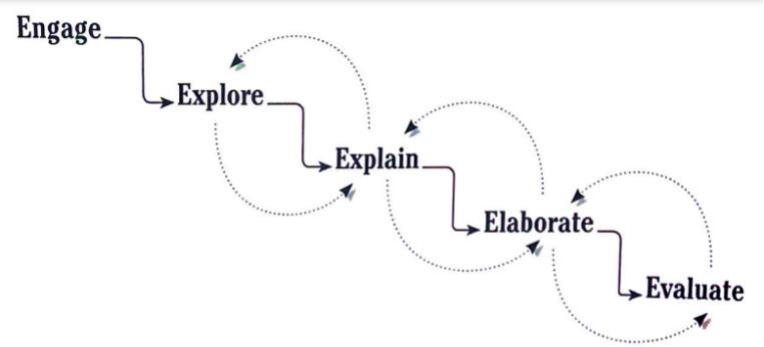


Figure 4. Responsive nature of the 5E Model (Chitman-Booker & Kopp, 2013).

CHAPTER THREE

METHODOLOGY

The Focus on MSSE Capstones

The students who are a part of the Master of Science in Science Education (MSSE) program at Montana State University come from all over the country. Each person who is a part of the program is a science educator. To complete the program, MSSE students design and carry out an action-based research project, present their findings, and write a culminating Capstone paper. I chose to focus this review around MSSE Capstone papers because of the diversity and experience that each MSSE member brings to the program. MSSE students works with K-12 participants from across the United States, and as a result, this review can draw conclusions about the effects of the 5E Model on a variety of secondary science classrooms and student populations.

Collection and Organization of MSSE 5E Model Capstones

The search for research articles began by screening the library of published MSSE Capstone papers and taking note of the title of each one. If a paper's title focused on any topic regarding the 5E Model, I downloaded the article and saved it for further analysis. I ended up finding twenty-six research articles about the 5E Model.

After accumulating the research articles, I created a table to keep track of the author, the title of the paper, year of publication, the topics the paper addressed, and any notes that I had about the paper (Appendix A). I knew that I wanted to focus on understanding the effects of 5E

model on secondary education classrooms, which resulted in the removal of research articles that related to primary education.

I then shifted my focus on determining the commonalities of the articles. I noticed that many articles addressed student performance, student engagement and student interest in science. These commonalities helped determine the three sub questions for this review. There were three additional papers from my initial search that were pulled, as their focus did not align with the focus topics described above. Overall, I had twenty-one research articles to analyze and draw conclusions from about the effectiveness of the 5E Model on student performance, student engagement, and student interest in science. For each sub-question, I went through each capstone article and summarized their methodologies and results. This not only helped organize the articles, but it also helped identify common themes and sample sizes. Analyzing each article also allowed me to indicate which studies were unique and deserved to be individually highlighted within this paper.

CHAPTER FOUR

A REVIEW AND ANALYSIS OF MSSE CAPSTONE PAPERS

Effectiveness of the 5E Model on Student Performance

Out of the 21 original studies which assessed the effects of the 5E Model, 19 of them had a section that focused on student performance. Out of those 19 studies, 68.4% of the papers had a common methodology used to measure student performance. The researchers taught units ranging in length from two weeks to one month. Some of the data collection spanned over two to four units; however, some units were very large and were split into two smaller units. Each unit was either taught using the traditional teaching model or by implementing the 5E Model. A pre and posttest was administered in each unit to measure the overall change in student understanding of key concepts. Overall, 69.2% of the studies concluded that the 5E Model had a positive impact on student performance (Acic, 2012; Casper, 2015; Cramer, 2012; Dalbey, 2018; Generaux, 2014; Hokkanen, 2011; Ingwaldson, 2012). In addition, 15.4% indicated that the 5E Model improved student performance, but the growth was not statistically significant (Kenealy, 2013; Wieloch, 2020). The remaining 15.4% reported that the traditional teaching method had positive impact on student performance, rather than the 5E Model (Lippert, 2022; Lynn, 2012).

Three of the 5E Model studies produced notable discoveries. One study, conducted by Michelle Dodge (2017), taught students a new science topic every two weeks for two months. The students either learned the topic through the direct, traditional teaching model or through inquiry-based instruction with the 5E Model. Students were given formative assessments as well as a pre and post assessment for each topic to track student learning. In addition, Dodge also

accounted for the range of student's learning styles and classroom abilities by breaking up the classroom into three differentiated learning levels: a foundational level, a standard level, and an accelerated level. Students were continuously monitored throughout the school year to ensure they were grouped accurately. The results uncovered that student learning under either the traditional teaching method or through the 5E Model both showed growth from pretest to posttest. Students showed growth whether they learned from traditional teaching methods or through the implementation of the 5E Model; however, students who were taught using the 5E Model demonstrated higher gains than those who learned from a traditional teaching method (Figure 5).

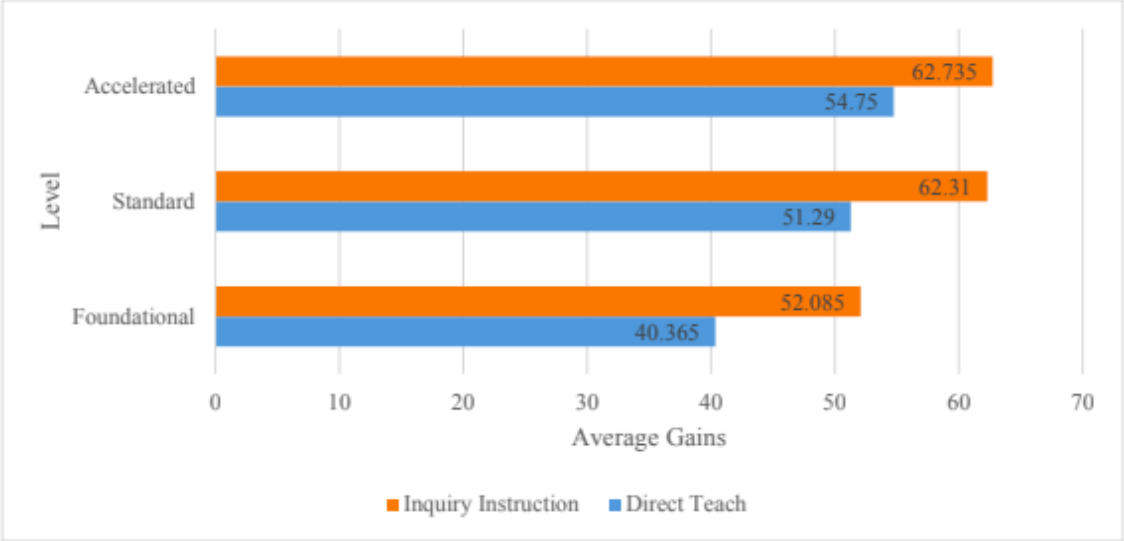


Figure 5. Pre and posttest gains of differentiated levels of students, (Dodge, 2017).

The 5E Model appeared to impact foundational level students and standard level students the most, where average student learning gains increased between 11.02-11.72 points (Figure 5). The accelerated students appeared to be impacted the least, displaying the smallest difference between the two teaching methods (7.982 points). The learning gains made by students at the foundational level for the 5E Model were statistically significant ($t=1.34$, $p<.1$, $df=12$), whereas

the standard level group did not show statistically significant improvements (t=1.24, p>.1, df=31). The 5E Model had a slight positive impact on the accelerated group, though the changes were not statistically significant (p value = 0.1168).

Another study showing additional impacts of the 5E Model on student performance was carried out by Shari Generaux (2014). At the time of the study, Generaux worked at a school with both a high poverty rate, and a high proportion of students of color and students who identified as English Language Learners (ELLs). A component of the study investigated how the 5E Model impacted students from various groups, such as ethnicity and gender. The study design incorporated three units instructed through traditional teaching method (pre-treatment) and three units implementing the 5E Model (treatment). The average of each posttest assessment score from each unit was calculated based on student ethnicity and gender (Figures 6; Figure 7). The results uncovered that the 5E Model positively impacted almost every ethnicity group, regardless of the student's gender. Latino males showed an average increase of 5%, while African American and Vietnamese females displayed gains of 11% and 8%, respectively.

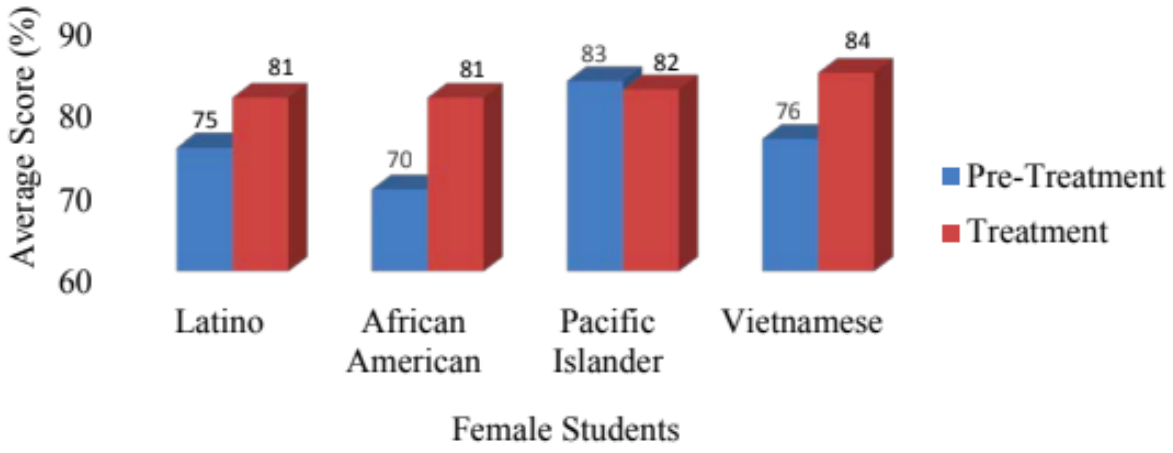


Figure 6. Average assessment scores for females by ethnicity, (*N*=59) (Generaux, 2014).

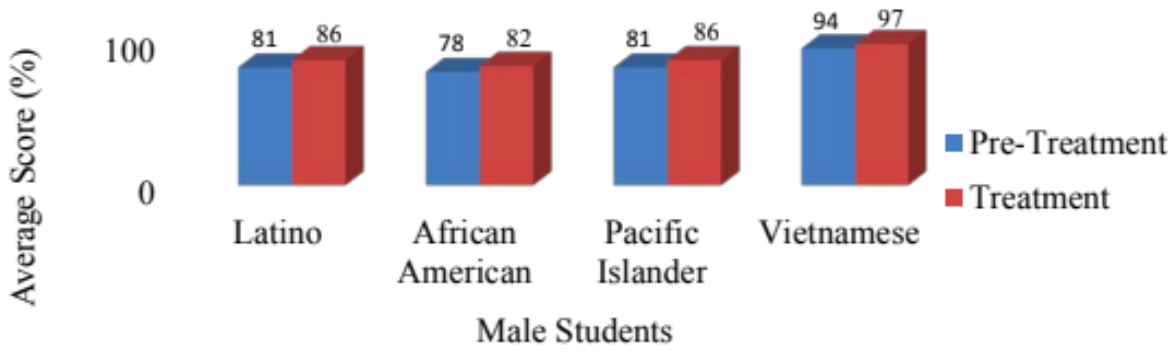


Figure 7. Average assessment scores for males by ethnicity, (*N*=43) (Generaux, 2014).

Students who identified as an English Language Learners were also positively impacted by the 5E Model (Figure 8). Female ELLs improved in their assessment by 7%, while male ELL students increased their average score by 6%. The author noted that the average score of the females in the treatment group was a 76% which was under the overall class average of 83%, whereas the males in the group performed slightly higher than the class average, finishing with an average of 85%.

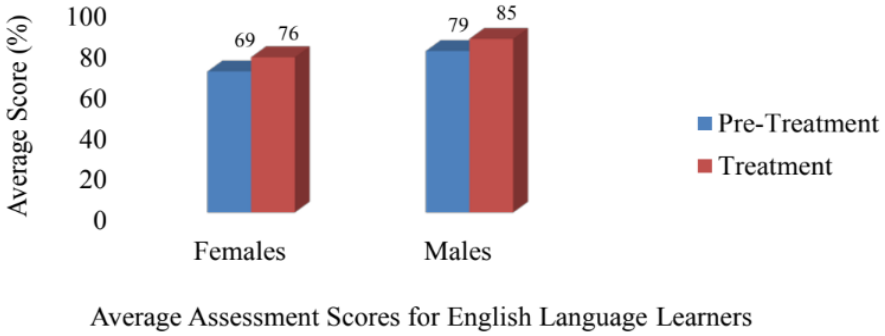


Figure 8. Average assessment scores for English Language Learners, (*N*=24) (Generaux, 2014).

The final study worth noting was conducted by Mercedes Lippert (2022). In Lippert's research study, students were placed into two subgroups, a lower-level group, and a higher-level

group. Students were placed in the lower-level group if they scored below 10% on a preassessment test. Two different class periods over the course of two units were used to collect data. For the first unit, one class was taught through a traditional method, while the other class was taught using the 5E Model. In the second unit, the methods of instruction were swapped for the two class periods. The unique part of the Lippert study is the comparison of the post test scores of lower-level students versus higher-level students across the two teaching methods (Figure 9). In the traditional posttest results, there is a significant gap, approximately 20%, in the average score of a lower-level student compared to the higher-level student. In contrast, the gap between the lower-level students and the higher-level students is much smaller when the 5E model is employed, where the approximate difference in the average posttest score is 7%. Lower-level students performed better with the 5E Model teaching method, while for higher-level students' performance levels decreased. Although Lippert's study was one of two studies that concluded that the traditional teaching method had a slightly more positive impact on student learning compared to the 5E Model, it also revealed that the 5E Model has the potential to close the gap of achievement between lower-level students and higher-level students.



Figure 9. Comparison of post-test results between subgroups and between non- treatment and treatment groups, (*N*=34) (Lippert, 2022).

The Impact of 5E Model on Student Engagement

Eight out of the original 21 research articles addressed the effects of the 5E Model on student engagement, with 87.5% of them finding that the 5E Model positively impacted student engagement. Five out of the nine studies used common methodology to track student engagement, where the researcher had a colleague or administrator come into their classrooms and observe anywhere from two to eight lessons. The classroom observers recorded on or off task behaviors on a tally sheet developed by the researcher. Each researcher created a clear list of on or off task behaviors so that acceptable behaviors could be classified accurately. Some on/off task behaviors were listed separately, while other behaviors were embedded into the tally sheet (Appendix B) (Acic, 2022, Alger, 2015; Ali, 2020; Dodge, 2017; Ingwaldson, 2020; Lynn, 2012; & McCollough, 2022, Wieloch, 2020).

It is important to note two major differences between the studies that tracked student engagement. Some observations took place for the duration of the entire lesson, while others were only observed for ten minutes. The number of students the observers were asked to watch during their time in the classroom also varied drastically. Some observers watched only four students, some ten, and others the entire class. It is unclear how these differences may have impacted the results, but they are something to keep in mind.

For studies where student engagement was tracked throughout the entire lesson, the differences in student engagement between traditional lessons and 5E lessons were astounding. Ali (2020) reported 80% off-task behaviors during the traditional lessons and only 20% off-task behaviors during 5E lessons (Figure 10). The observer for Dodge (2017) was tasked with observing off-task behaviors during different stages of a lesson. In the traditional lesson, a large

part of the class is teacher-focused, with additional time typically dedicated to group work and/or demonstrations or labs. The 5E lesson for Dodge included the first four phases of the 5E cycle, however the 5E Cycle can be stretched out through multiple lessons. The students were much more engaged during the stages of the 5E lesson as compared to the stages of the traditional lessons (Figures 11 & 12).

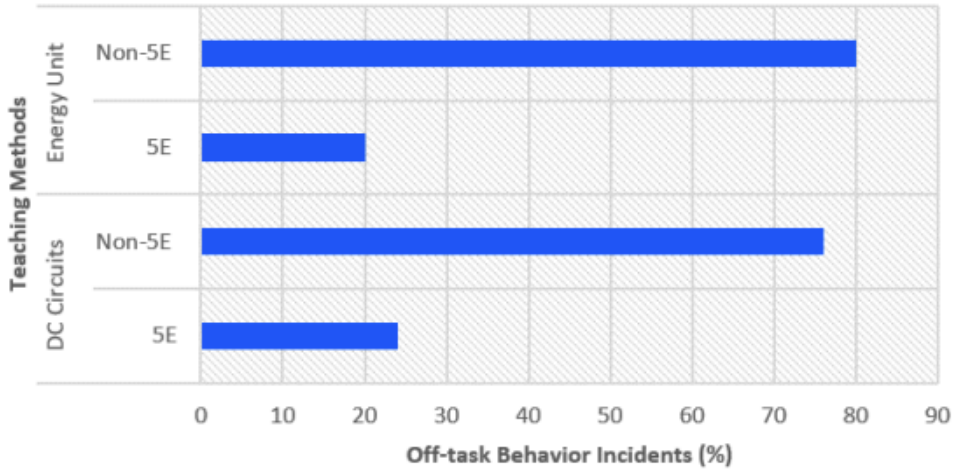


Figure 10. Percentage of off task incidents, (*N*=50) (Ali, 2020).

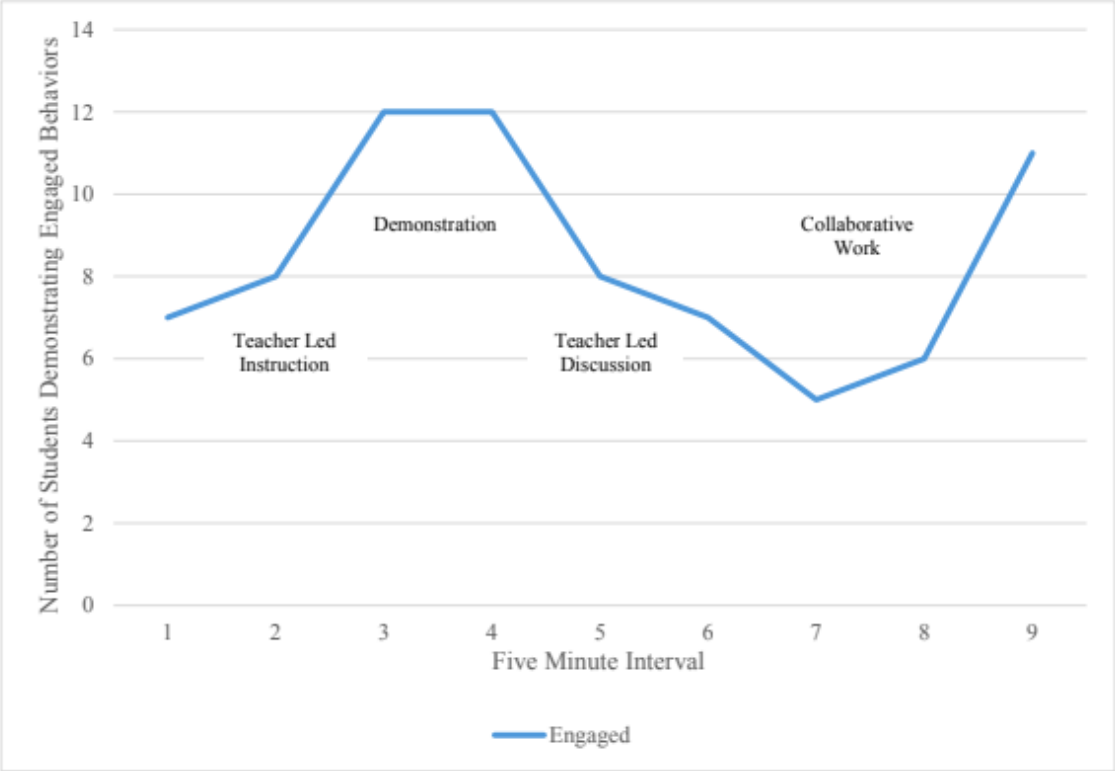


Figure 11. Student engagement tally for traditional lessons, (*N*=12) (Dodge, 2017).

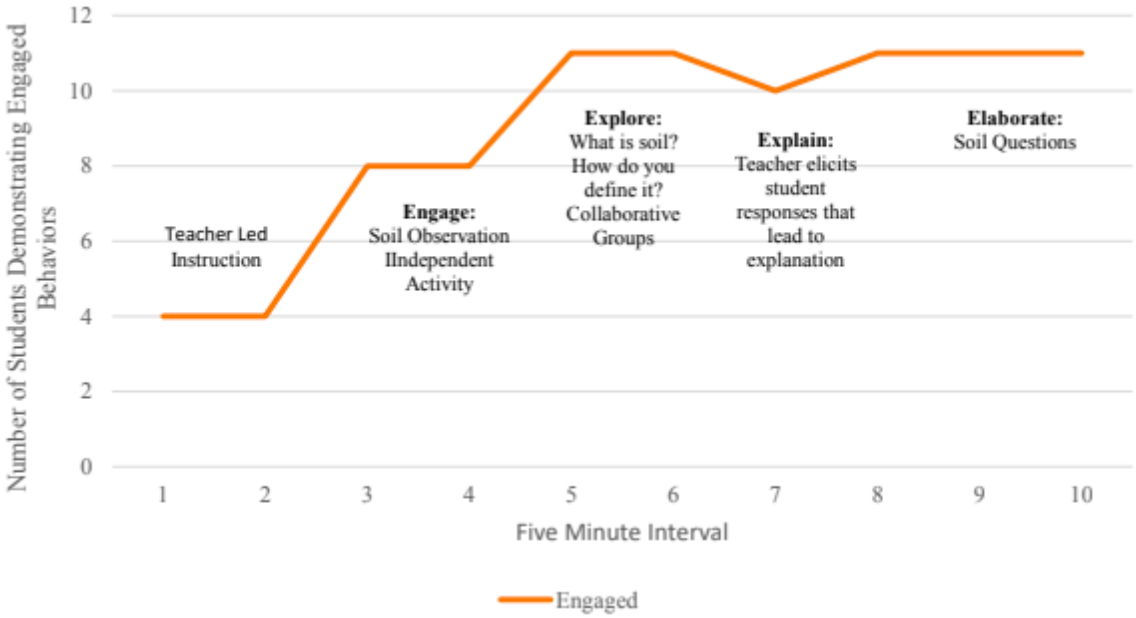


Figure 12. Student engagement tally for 5E lessons, (*N*=11) (Dodge, 2017).

Only one study reported higher student engagement using the traditional teaching method. McCullough (2022) found 53% of all off-task behaviors were observed during 5E lessons, as compared to the 47% of off-task behaviors for traditional lessons. McCollough used the same methods of collecting student engagement data as described above; however, students did have access to Chromebooks for the purposes of conducting research and watching videos. None of the other studies reported the use of any computers during the lesson. McCullough found that 27% of all off-task behaviors were linked to Chromebook usage. McCollough did reflect on this statistic and noted how easy it was for students to get distracted by ads or noneducational websites, even stating that they too are easily distracted by technology.

Effectiveness of the 5E Model on Increasing Student Interest in Science

Are students enjoying their time while they are in their science classes? Are students interested in making connections to the real world? Are students interested in science outside of the classroom? These were all the questions I asked myself as I read through research papers to answer the question, "Does the 5E Model increase students' interest in science?" Out of the 21 original articles, 10 of them addressed changes in student interest. 100% of these studies reported that the 5E Model had a positive impact on student interest. Some of the impacts were more drastic than others, but overall, each study did have a positive shift in interest. All the studies used similar methodologies, where students answered a series of survey questions. The surveys did vary, however, in the types of questions students answered. In some studies, students completed a survey each day, while in others, students completed one survey before and after individual lessons or units. (Acic 2012; Ali, 2020; Casper, 2015; Chase, 2016; Cornelius, 2012; Hall, 2021; Ingwaldson 2020; Kenealy, 2013; Lippert, 2022; Nilsen, 2013).

In Ali (2020), students completed an Attitude Survey at the end of each unit. Ali had one class learning the unit through traditional teaching and another class learning the unit through the 5E Model structure. After the first unit, 66% of students found that learning physics through the 5E learning cycle was enjoyable, and that they were more engaged and were encouraged to read and learn more. Only 21% of students found learning physics enjoyable through traditional teaching. In the second unit, 68% of students found that learning physics through the 5E learning cycle was enjoyable while only 20% of students preferred learning physics through the traditional teaching model.

In Cornelius (2012) students completed surveys before and after the implementation of the 5E Model. The first survey was a Nature of Science (NOS) survey which addressed students' ability to interpret facts versus fiction, students' opinion on the science taught in school being related to their real lives, and students' ability to recognize the connections between what they learned in class and what they observe in their everyday lives. The results uncovered that the 5E Model increased student responses to each component of the NOS survey. The other survey given to students was an Attitude Survey, which gauged whether students enjoyed science, enjoyed coming to class, and whether students enjoyed the labs conducted. There was no change in how enjoyable the labs conducted were; however, students did state they looked forward to coming to class more and found science to be enjoyable under the 5E Model of instruction (Figure 13).

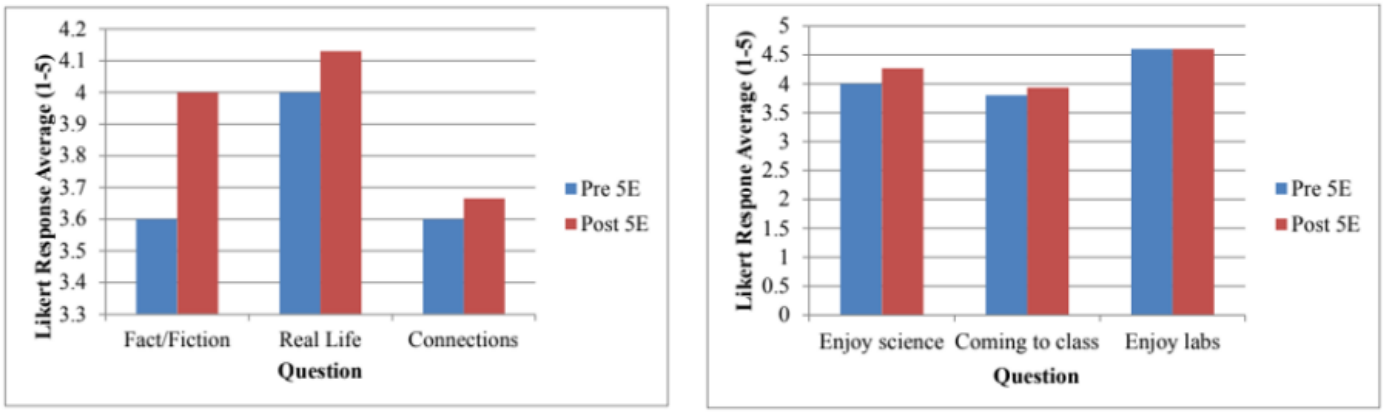


Figure 13. Left: Pre and post Nature of Science Survey responses, (*N*=15) and right: Pre and post Attitude Survey response averages, (*N*=15) (Cornelius, 2012).

Hall (2021) investigated how the 5E Model impacted science literacy. Students were given a Science Literacy Survey to reflect on how reading about current events in science impacted their attitudes about science. The survey addressed three main topics: reading current events increases curiosity about the world, reading about science increases the enjoyment to see other people's opinions and views, and reading about science increases enjoyment about hearing new ideas and topics (Figure 14). Hall reported that after implementing the 5E Model, students strongly agreed or agreed that reading current events in science made them more curious about the world around them (+3%), students enjoyed hearing other opinions and views (+3%), and they liked to hear about new ideas and new topics (+14%). The growth displayed for students interested in hearing about new ideas and topics in science demonstrates their newfound interest in science.

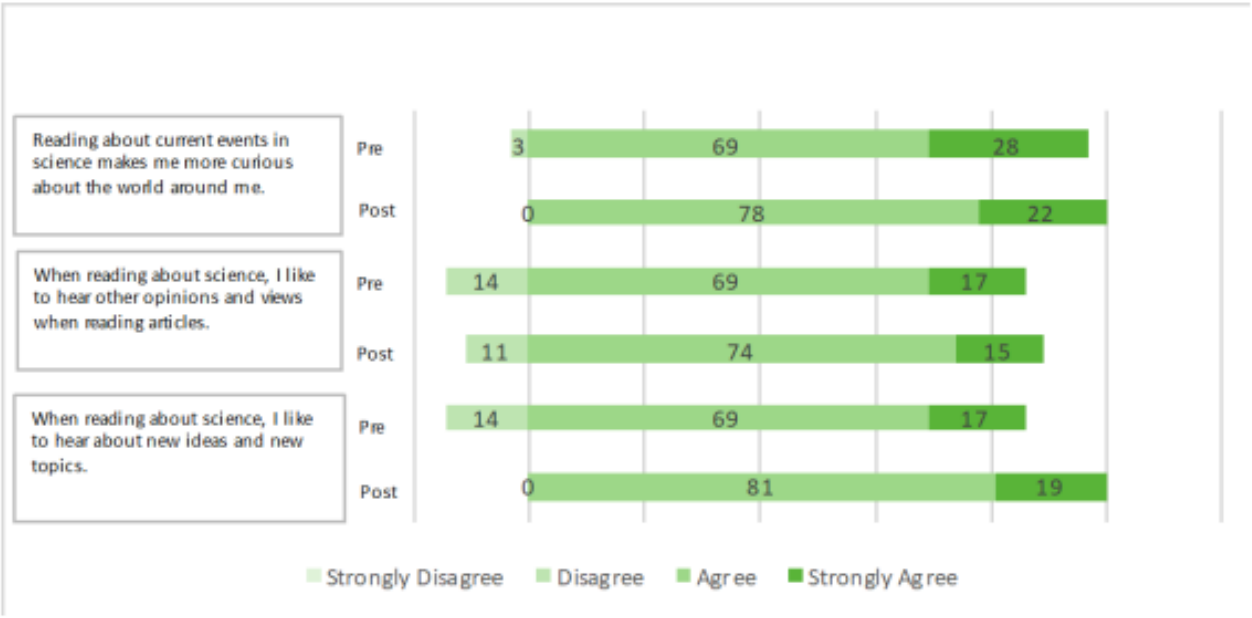


Figure 14. Scientific Literacy Survey – Science Related Attitudes, (pre-, *n*=29), (post-, *n*=27) (Hall, 2021).

Key Findings from the Review

A review of the nineteen articles investigating the impact of the 5E Model on student performance revealed that 79% of researchers reported that the 5E Model had a statistically significant positive impact on student performance in the classroom in comparison to traditional teaching methods. 10.5% of these studies also reported that the 5E Model positively influenced student performance, however the results were not statistically significant. In contrast, another 10.5% of the studies reported that the 5E Model negatively impacted student performance when compared to units taught using traditional teaching methods (Figure 15). Out of the eight articles that focused on the impact of the 5E Model on student engagement, seven reported a positive impact when utilizing the 5E Model in comparison to lessons taught through traditional teaching methods, whereas one study concluded that lessons taught through traditional

teaching methods resulted in higher student engagement (Figure 16). All ten capstone studies investigating the effect of the 5E Model on students' interest in science concluded that the 5E Model improved students' interest in science (Acic, 2022; Alger, 2015; Ali, 2020; Casper, 2015; Chase; 2016, Cornelius; 2015; Cramer, 2012; Dalbey, 2018; Dodge, 2017; Generaux, 2014; Hagerman, 2012; Hall, 2021; Hokkanen, 2011; Ingwaldonson, 2020; Kenealy, 2013; Lippert, 2022; Lynn, 2012; McCollough, 2022; Nilsen, 2013; Watt, 2013; Weiloch, 2020).

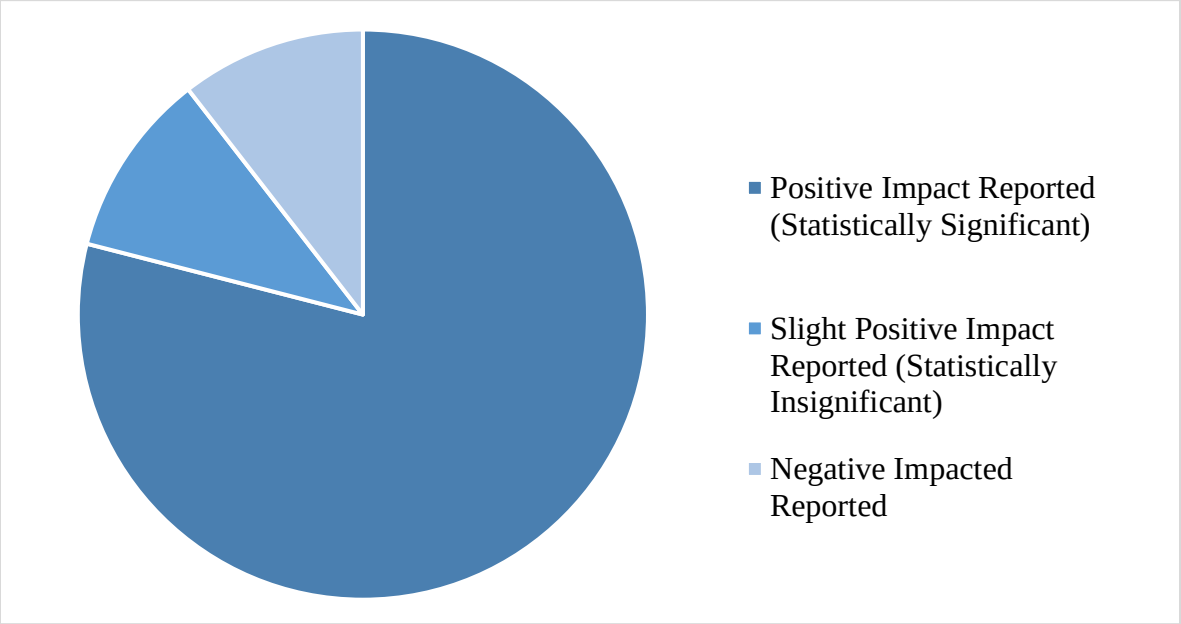


Figure 15. The reported impact of the 5E Model on student performance in secondary classrooms in comparison to traditional teaching methods, (*n*=19).

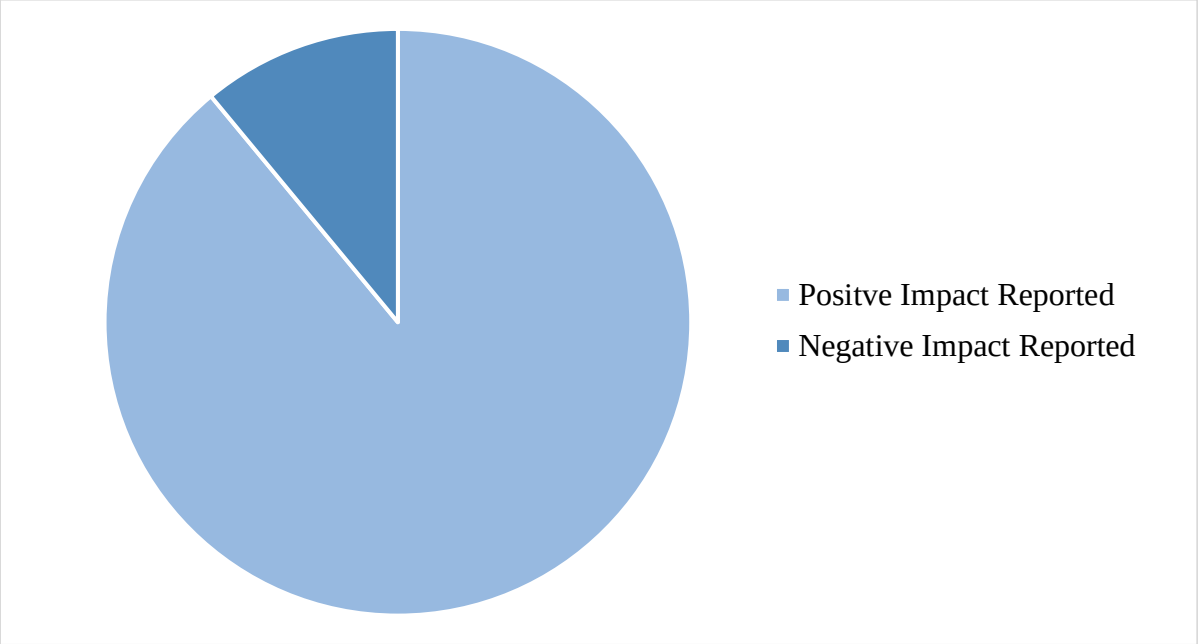


Figure 16. The reported impact of the 5E Model on student engagement in secondary classrooms in comparison to traditional teaching methods, (*n*=8).

CHAPTER FIVE

CLAIM EVIDENCE AND REASONING

Claims From the Study

Colorado recently adopted the Next Generation Science Standards as the new state science standards. As a teacher, I noticed lower student performance and interest in my class when I first started implementing these new standards in my classroom. This caused me to search for a new way to incorporate these standards and help alleviate some of the struggles I faced. One way that the standards can be carried out in the classroom is with the 5E Learning Model. The goal of this review was to determine the impact of the implementation of the 5E Model in secondary science classrooms on student performance, student engagement and student interest in science compared to traditional teaching methods. Twenty-one research articles from the MSSE capstone library at Montana State were analyzed to draw conclusions for this study. These research articles were organized three different ways. They were first sorted by focus questions, then by methodologies and finally by their results. This helped to identify common themes, unique cases, and reveal key differences.

As a result of this review and analysis of MSSE Capstone papers on the 5E model, I make the following claims:

1. The 5E Model improved student performance in secondary classrooms.
2. The 5E Model positively impacted student engagement in secondary classrooms.
3. The 5E Model significantly improved student interest in science in secondary classrooms.

4. The 5E Model had a clear, positive impact on students in secondary science classrooms.

Based on the research, I claim that the utilization of the 5E Model had a significant impact on student performance. Nineteen out of the 21 articles specifically addressed how the 5E Model impacted student performance when compared to traditional teaching methods. Some of these studies were very specific to the types of students being taught through the 5E Model. For example, one study investigated how the 5E Model impacted student performance for different demographics such as ethnicity and primary language, while another study looked at how the 5E Model affects students whose levels of initial understanding were different. Many studies tracked student performance data by teaching one or more units through a traditional style of teaching, while the next unit or units were taught using the 5E Model. Pre and posttest surveys were employed to examine the overall student gains. Out of the 19 studies, approximately 79% found that the 5E Model had a positive impact on student performance, including ones that focused on student demographics and initial levels of understanding. In addition, 10.5% concluded that the 5E Model positively impacted student performance, though the results were not statistically significant.

Claims can also be made that the 5E Model positively impacted student engagement. Eight out of the 21 research articles investigated the impact the 5E Model had on student engagement. To track student engagement, many researchers taught multiple traditional lessons and multiple lessons utilizing the 5E Model. While the researchers taught the lesson, an observer tracked student engagement using a carefully developed tally sheet with predetermined off-task and/or on-task behaviors. Approximately 88% of the studies concluded that the 5E Model

increased student engagement within the classroom. Several studies reported substantial differences in student engagement for lessons taught using the 5E Model. In one study, 80% off-task behaviors took place during the traditional lessons and only 20% of off-task behaviors during 5E lessons.

Lastly, the 5E Model had a substantial impact on students' interest in science, where ten studies examined the impact of the 5E Model on student interest in science. To track the impact of the 5E Model on student interest, each study employed student surveys. The timing of these surveys varied from study to study; however, many researchers asked students to complete the survey before and after implementing the 5E Model. The types of questions also varied. For example, in one study, the survey asked students whether the class was more enjoyable. In another study, students were asked if they were able make connections from what they learn about in class to what they observe in everyday life. Another survey asked students if reading current events in sciences made them more interested in the world around them. No matter what survey questions were asked, the outcome was always the same, as 100% of the studies found that the 5E Model improved student interest in science. Some studies showed larger gains in student interest, but overall, gains were observed in each study.

Through a variety of methodologies, class sizes, class demographics, and student levels of understanding, the findings are overwhelmingly in favor of the 5E Model. Although the sample size is small, the evidence suggests that the 5E Model does have a significant, positive impact on student performance, student engagement, and student interest in science in comparison to traditional teaching methods. The 5E Model has a positive influence on students in secondary science classrooms.

Value of the Study and Impact on the Author

Prior to Colorado adopting the Next Generation Science Standards, my classroom was very traditional. I would lecture from a presentation, students would take notes, complete practice problems, and the occasional lab would be conducted. However, using these traditional methods students weren't behaving and thinking like actual scientists. Traditional teaching methods give students all the answers, but rarely ask them to draw personal conclusions. When NGSS was adopted, I made the switch to phenomenon-based teaching, but it was poorly executed. The approach and length of the units had a negative impact on my students which in turn negatively impacted me. This went on for years and I developed a distaste for the new standards because I could not implement them successfully. The 5E Model was introduced to me and it gave me a new sense of hope, but I was skeptical. Does this teaching method actually work?

The results of this review have given me a new sense of hope for phenomenon-based teaching, NGSS, and re-ignited my passion to teach science. I hope other teachers who are struggling in the same areas as I stumble across this research and know there is a method to help students develop their science literacy. The 5E model suggests to me there is a way to engage students, increase their interest in science, teach students content and help them perform better by forcing them to engage in higher level thinking. During the study, I began utilizing the 5E Model in small doses within my own classroom and I could immediately see the effects on my students, especially in areas of student engagement and their willingness to think critically. In the upcoming school year, I plan on adapting my AP Chemistry curriculum away from a lecture-based structure to a more inquiry-based model by implementing 5E Model of Learning. This

goal will likely take multiple years to achieve and execute proficiently, but it is a goal that I am passionate about pursuing.

Consideration for Future Research

One future opportunity for research is exploring the question, "How does the implementation of the 5E Model in an AP science class impact students AP exam scores?" I often wonder if there is a reason why AP classes are often taught through traditional teaching methods? Do teachers just lecture or assign readings of the required material so that students are exposed to all the objectives that should be covered? Is there simply not enough time to teach college-level content in a different way? This can't be true, as students who can extend their thinking outside of what they learned in class are typically the ones who earn high scores on the AP exams. The 5E Model requires students to extend their thinking to new scenarios to demonstrate mastery of a topic, which in theory should help students answer harder extension questions seen on the AP exams.

Another research opportunity came from a question that constantly went through my mind as I analyzed these research articles. How well trained were each of these authors to carry out the 5E Learning Model and did that impact their results? Were the more well-versed authors the ones that had the most significant gains in student performance, engagement, and student interest? I would like to conduct a study to answer this question. I would like to have two groups of teachers, one group that is familiar with the idea of the 5E Model and one group who has received formal training and practice on how to create and carry out 5E Model lessons. The study would task each educator with teaching the same science units and the methods of analysis

would assess student performance, engagement, and interest to see if there is a significant difference because of formal 5E model training.

REFERENCES CITED

Acic, V. (2022). *Anchoring phenomenon and 5Es in high school physics* [Master's thesis, Montana State University]. Montana State University Library.

Alger, K. T. (2015). The impact the 5E Learning Cycle Model has on student achievement and engagement in a middle school science class.

Ali, W. (2020). *The 5E Learning Cycle vs. traditional teaching methods and how they affect student achievement rate, interest, and engagement in a high school physics classroom* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/15996

American Modeling Teachers Association. (2019, December 9). Connections to NGSS and 21st century skills. Transforming STEM Education. https://www.modelinginstruction.org/connections-to-ngss-and-21st-century-skills/

Bybee, R. (2009). The BSCS 5E Instructional Model and 21st century skills. The national academies. https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_073327.pdf

Bybee, R. (2014). The BSCS 5E Instructional Model: Personal reflections and contemporary implications. *Science & Children*, *51*(8), 10–13.

Casper, K. M. (2015). *Increasing student achievement in science through the use of the 5E Instructional Method* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/9244

Chase, A. M. (2016). *The 5E Instructional Model for the next generation chemistry classroom* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/10038

Chitman-Booker, L., & Kopp, K. (2013). *The 5Es of inquiry-based science*. Shell Education.

Cornelius, M. (2012). *The 5E Learning Cycle and students understanding of the nature of science* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/1112

Cramer, K. B. (2012). *Impact of constructivism via the biological sciences curriculum study (BSCS) 5E Model on student science achievement and attitude* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/1121

Dalbey, L. H. (2018). *The impact of the 5E Learning Cycle on seventh grade life science students' learning and retention of science concepts* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/14776

Denver Public Schools School Finder. (n.d.). School Mint. https://dps.schoolmint.net/school-finder/schools/74/east-high-school

Dodge, M. M. (2017). *The effect of the 5e instructional model on student engagement and transfer of knowledge in a 9th grade environmental science differentiated classroom* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/13652

Fix, D. (2012). Disappearing Styrofoam Cup. YouTube. https://www.youtube.com/watch?v=rqX3Aztej0U.

Generaux, S. L. (2014). *The effects of the 5E Learning Cycle on student integration of science vocabulary* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/3550

Green, A. (2021). Traditional teaching and learning strategies: What actually works? What is it? Why use it? *Traditional teaching and learning strategies*. https://www.itac.edu.au/blog/teaching-strategies/traditional-teaching

Hagerman, C. L. (2012). *Effects of the 5E Learning Cycle on student content comprehension and scientific literacy* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/1404

Hall, E. M. (2021). *Scientific literacy in a 5E secondary science classroom [*Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/16487

Harjo, K. (2021). What is the 5E Model and how do you use it to teach science? YouTube. https://www.youtube.com/watch?v=Ktf1xepeaaI&t=511s

Watt, M. A. (2013). *Effect of the 5E Instructional Model on student understaning and engagement in high school chemistry.* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/2833

Hokkanen, S. L. (2011). *Improving student achievement, interest and confidence in science through the implementation of the 5E Learning Cycle in the middle grades of an urban school* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/1487

Ingwaldson, H. M. (2020). *5E instruction in a biology classroom* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/16324

Kenealy, K. R. (2013). *The effects of the 5E Learning Cycle on understanding high school biology* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/2806

Lesley University. (n.d.). Empowering students: The 5E Model explained. https://lesley.edu/article/empowering-students-the-5e-model-explained#:~:text=The%20findings%20of%20Atkin%20and,Explain%2C%20Elaborate%2C%20and%20Evaluate.

Lippert, M. (2022). *The 5E Model of Learning in a chemistry classroom* [Master's thesis, Montana State University]. Montana State University Library.

Llewellyn, D. (2007). Inquire Within: implementing inquiry-based science standards in grades 3-8. Thousand Oaks, CA: Corwin Press.

Lynn, H. B. (2012). *Guided inquiry using the 5E Instructional Model with high school physics* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/1767

McCollough, D. F. (2022). *The effects of the 5E Learning Cycle on high school science students* [Master's thesis, Montana State University]. Montana State University Library.

McGraw Hill. (n.d.). *The 5E Model and More Within Inspire* . Science K–12 Science Curriculum & Pedagogy: Inspire science: McGraw-Hill. https://www.mheducation.com/prek-12/program/microsites/MKTSP-AIB05M0/pedagogy.html

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press. https://10.17226/13165

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Nilsen, J. E. (2013). *Interest development and the 5E Model* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/2812

Science Resource Center. (2022). Importance of Phenomena. https://ngss.sdcoe.net/Phenomena-and-the-NGSS/The-Importance-of-Phenomena

Vigeant, F. (2016, September 21). The Traditional Model of Science Instruction. NGSS & STEM Curriculum for Grades K-8. https://www.knowatom.com/blog/the-traditional-model-of-science-instruction

Wieloch, N. F. (2020). *The 5E instructional method in high school* [Master's thesis, Montana State University]. Montana State University Library. https://scholarworks.montana.edu/xmlui/handle/1/16339

APPENDICES

APPENDIX A:

ORGANIZATION OF CAPSTONES

Author	Article Title	Year	Topics Address	Notes
Vasilij Acic	ANCHORING PHENOMENON AND 5Es IN HIGH SCHOOL PHYSICS	2022	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Kellen Thomas Alger	THE IMPACT THE 5E LEARNING CYCLE MODEL HAS ON STUDENT ACHIEVEMENT AND ENGAGEMENT IN A MIDDLE SCHOOL SCIENCE CLASS	2015	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Student Interest in Science	
Walayat Ali	THE 5E LEARNING CYCLE VS. TRADITIONAL TEACHING METHODS AND HOW THEY AFFECT STUDENT ACHIEVEMENT RATE, INTEREST, AND ENGAGEMENT IN A HIGH SCHOOL	2020	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	

	PHYSICS CLASSROOM			
Kyle Mark Casper	INCREASING STUDENT ACHIEVEMENT IN SCIENCE THROUGH THE USE OF THE 5 E INSTRUCTIONAL METHOD	2015	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Amy M. Chase	THE 5E INSTRUCTIONAL MODEL FOR THE NEXT GENERATION CHEMISTRY CLASSROOM	2016	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	Focused on science literacy
Matthew Cornelius	THE 5E LEARNING CYCLE AND STUDENTS UNDERSTANDING OF THE NATURE OF SCIENCE	2012	• Student Engagement • Student Performance • Student Ability to Think • Student Retention	• Student performance is based off of lab grades vs. the traditional exam scores • 5E Lab grades are not compared to traditional lab grades

			• Students Interest in Science	
Karla B. Cramer	IMPACT OF CONSTRUCTIVISM VIA THE BIOLOGICAL SCIENCES CURRICULUM STUDY (BSCS) 5E MODEL ON STUDENT SCIENCE ACHIEVEMENT AND ATTITUDE	2012	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Joe Colin Crider	THE 5E LEARNING CYCLE VS. TRADITIONAL TEACHING METHODS AND HOW THEY AFFECT STUDENT ACHIEVEMENT, INTEREST, AND ENGAGEMENT IN A THIRD GRADE SCIENCE CLASSROOM	2013	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Students too young to use for this study.
Leslie Heather Dalbey	THE IMPACT OF THE 5E LEARNING CYCLE ON SEVENTH GRADE LIFE SCIENCE STUDENTS' LEARNING AND	2018	• Student Engagement • Student Performance • Student Ability to Think	• Student engagement can be observed through absences. • Interesting figures about how traditional vs 5E impacts the teachers.

	RETENTION OF SCIENCE CONCEPTS		• Student Retention • Students Interest in Science	
Michelle Marie Dodge	THE EFFECT OF THE 5E INSTRUCTIONAL MODEL ON STUDENT ENGAGEMENT AND TRANSFER OF KNOWLEDGE IN A 9th GRADE ENVIRONMENTAL SCIENCE DIFFERENTIATED CLASSROOM	2017	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Student performance and engagement is also broken down by level of student (accelerated, standard, and foundational)
Shari Lynn Generaux	THE EFFECTS OF THE 5E LEARNING CYCLE ON STUDENT INTEGRATION OF SCIENCE VOCABULARY	2014	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Student performance is broken down by ethnicities.
Charlotte L. Hagerman	EFFECTS OF THE 5E LEARNING CYCLE ON STUDENT CONTENT	2012	• Student Engagement • Student Performance	• Student performance is based on lab write ups.

	COMPREHENSION AND SCIENTIFIC LITERACY		• Student Ability to Think • Student Retention • Students Interest in Science	
Emily Martin Hall	SCIENTIFIC LITERACY IN A 5E SECONDARY SCIENCE CLASSROOM	2021	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Susanne Lorraine Hokkanen	IMPROVING STUDENT ACHIEVEMENT, INTEREST AND CONFIDENCE IN SCIENCE THROUGH THE IMPLEMENTATION OF THE 5E LEARNING CYCLE IN THE MIDDLE GRADES OF AN URBAN SCHOOL	2011	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Tyler Hollow	DOES TEACHING SCIENTIFIC INQUIRY	2018	• Student Engagement	

	THROUGH THE 5E LEARNING CYCLE AFFECT NINTH GRADE EARTH SCIENCE STUDENTS' ENGAGEMENT AND CONCEPTUAL UNDERSTANDING?		• Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Holly Marie Ingwaldson	5E INSTRUCTION IN A BIOLOGY CLASSROOM	2020	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Kendra Kanduch	THE EFFECTS OF THE 5E INQUIRY TEACHING COMPARED TO TRADITIONAL TEACHING IN A SIXTH GRADE SCIENCE CLASS	2015	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Cannot use, students are too young

Kevin Raymond Kenealy	THE EFFECTS OF THE 5E LEARNING CYCLE ON UNDERSTANDING HIGH SCHOOL BIOLOGY	2013	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Mercedes Lippert	THE 5E MODEL OF LEARNING IN A CHEMISTRY CLASSROOM	2022	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	
Hermes B. Lynn	GUIDED INQUIRY USING THE 5E INSTRUCTIONAL MODEL WITH HIGH SCHOOL PHYSICS	2012	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Student engagement data includes teacher and student's perspective of engagement.

Margaret K. Magonigle	THE EFFECTS OF USING AN INQUIRY-APPROACH THROUGH THE 5 E LESSON FORMAT ON MIDDLE SCHOOL EARTH AND SPACE SCIENCE STUDENTS	2011	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Study was conducted on 8th grade students. • Not helpful for my particular study.
Robert David Maul	THE EFFECTS OF GAMIFICATION USING THE 5E LEARNING CYCLE (QuIVERS) ON A SECONDARY HONORS CHEMISTRY CLASSROOM	2016	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Not helpful to my study. Data is a mix of gamification & the 5E Model.
David Frederick McCollough	THE EFFECTS OF THE 5E LEARNING CYCLE ON HIGH SCHOOL SCIENCE STUDENTS	2022	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	

John Eric Nilsen	INTEREST DEVELOPMENT AND THE 5E MODEL	2013	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Mainly focuses on student interest. • Links student interest directly to student performance which is an interesting touch.
Mary Ann Hirshfeld Watt	EFFECT OF THE 5E INSTRUCTIONAL MODEL ON STUDENT UNDERSTANDING AND ENGAGEMENT IN HIGH SCHOOL CHEMISTRY	2013	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	• Also includes the confidence levels of students. • Student performance data impacted
Natalie Frances Wieloch	THE 5E INSTRUCTIONAL METHOD IN HIGH SCHOOL	2020	• Student Engagement • Student Performance • Student Ability to Think • Student Retention • Students Interest in Science	

APPENDIX B:

TALLY SHEET EXAMPLE 1

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 B. Tally sheet with on and off task behaviors listed below, (Dodge, 2017).

APPENDIX C:

TALLY SHEET EXAMPLE 2

McCollough Science Engagement Tally Sheet

Participation in this research is voluntary, and participation or non-participation will not affect a student's grades or class standing in any way.

Off Task Behavior	Occurrences
Playing with objects	
Calling Out	
Talking to Peers During Instructional Time/ Directions	
Noise Making	
Sleeping/ Head Down	
Cell Phone Use	
Off task Activity on Chromebooks (YouTube, work for other classes, shopping, games)	
Redirection by teacher	

Appendix C. Tally sheet with off task behaviors embedded in the tally sheet, (McCollough, 2022).