ANCHORING PHENOMENON AND 5Es IN HIGH SCHOOL PHYSICS

by

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ABSTRACT

The purpose of this study was to determine if the use of an anchoring phenomenon to drive instruction via the 5E Learning Cycle would increase the overall engagement and achievement with students in my physics courses. The non-treatment group received a teacher-led direct instruction approach, while the treatment group was taught utilizing an anchoring phenomenon and the 5E model to promote more student-led instruction. Pre- and post- test results were analyzed to determine student growth by comparing the mean and normalized gain values between groups. Observations, a behavior tally sheet, and pre- and post- Likert-type surveys helped to gather data on student engagement. The analyzed data indicates more student growth and engagement took place during the treatment units.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

School Demographics

When I was hired as a first-year teacher at William Fremd High School in 2014, I knew I was fortunate to be joining a school that was renowned for its academic rigor and success. William Fremd High School is located in Palatine, IL, an area in the Northwest suburbs of Chicago. The school has a population of 2,583 students, where 50.8% are classified as White, 32.2% Asian, 10.3% Hispanic, and 3.1% Black (Students, n.d.). Academics at William Fremd High School are held in high regard amongst the students, faculty, and the community as well. We offer nine Advanced Placement (AP) or dual-credit science classes alone, and follow a school initiative which has a goal of having our seniors accumulate 15 college credits by the time they receive their high school diploma. I currently teach four out of nine physics sections that our school offers, along with three other experienced teachers that make up our physics professional learning team (PLT).

Our physics class is run as a college-prep physics course. This means that the juniors that take the class would be prepared to take an AP science class their senior year, and the seniors in the course would be prepared for success in their first-year science classes that they would take in college. Due to these standards, the students in the class are all college-bound kids that have had a record of success in their prior science classes leading up to physics. This allows us to set high standards for the class, while also putting an emphasis on skills like collaboration and communication into most lessons.

Context of the Study

However, when I first got hired, I did not realize I was joining a department that was about to embark on fundamentally changing the way they delivered instruction to their students. When the Next Generation Science Standards (NGSS) were released in 2013 with the foundational research, *A Framework for K-12 Science Education,* they outlined the disciplinary core ideas, the science and engineering practices, and the cross-cutting concepts needed for a student to become a scientifically literate citizen in the 21st century (National Research Council, 2012). My first year of teaching was filled with departmental and Professional Learning Team (PLTs) meetings dedicated to navigating the transition from already established and proven curriculum, to one more aligned with NGSS. Fast forward eight years and my department is still navigating the waters on this transition. Many strides have been made with reworking district standards and assessments, but the approach to how curriculum is taught remained largely unchanged with many courses, physics included, until this year. As a physics PLT, we have taken it upon ourselves to rework certain units in order to fully align them with NGSS.

Focus Question

My focus question was, Will student engagement and understanding increase by creating a more interconnected unit with the incorporation of an anchoring phenomenon to drive instruction via the NGSS 5E learning model?

My sub-question was the following:

1. How does the incorporation of an anchoring phenomenon to drive instruction via the 5E Learning Cycle affect students’ attitudes toward science?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Inquiry-Based Learning

Inquiry-Based Learning (IBL) is a term that has been around since the turn of the 20th century. John Dewey first started the push to reform science education from a system of direct instruction, where the students were required to memorize and recall information that the teacher had stated, to a more realistic method of learning that is required of science, technology, engineering, and mathematics (STEM) professionals (Barrow, 2006). Dewey's restructuring of traditional science instruction put an emphasis on having the learner be an active participant on their journey to scientific understanding, and not just someone that is there to memorize facts (National Research Council, 2000). Since then, there have been forms of scientific inquiry that have taken root in the educational system, but the end goal is consistent across the board. Scientific inquiry provides an excellent means to help foster the development of students' habits of mind. Teachers who embrace inquiry-based classrooms promote critical-thinking skills, and empower students to become independent, lifelong learners (Llewellyn, 2013).

In 2012, the National Research Council (NRC) laid out a vision for what they believed all U.S. students should be familiar with by the time they graduate high school. The Next Generation Science Standards (NGSS) were released in 2013 with the foundational research, *A Framework for K-12 Science Education,* outlined the disciplinary core ideas, the science and engineering practices, and the cross-cutting concepts needed for a student to become a scientifically literate citizen in the 21st century (National Research Council, 2012). With the new

NGSS, inquiry was also at the forefront of their vision; however, they refer to it as practices (Llewellyn, 2013). The practices in the Framework reflect the requirements that scientists and engineers actually engage in as a part of their careers. The Science and Engineering Practices include (a) asking questions, (b) developing and using models, (c) planning and carrying out investigations, (d) analyzing and interpreting data, (e) using mathematics and computational thinking, (f) constructing explanations, (g) engaging in argument from evidence, and (h) obtaining, evaluating, and communicating information (National Research Council, 2012). While this seems like an ambitious mission, the beauty of the Framework is that it encourages educators to utilize methods they believe will work best to foster this environment for their classroom and students.

The 5E Learning Cycle

There are several ways to implement an IBL model into the classroom. Like the IBL, the 5E Learning Cycle is not a new model of instruction, it was originally proposed for elementary science programs in the 1960s by J. Myron Atkin and Robert Karplus (Llewellyn, 2013). Lately, it has become a popular model for high school teachers to approach scaffolding IBL effectively. “The 5E Learning Cycle model is a constructivist teaching strategy that includes five stages consistent with cognitive theories of how learning occurs: (1) Engagement, (2) Exploration, (3) Explanation, (4) Elaboration or Extension, (5) Evaluation” (Llewellyn, 2013, p. 84). During the Engagement stage, teachers try to draw prior knowledge from students and get them interested in the subject matter (Gejda & LaRocco, 2006). Teachers use various ways to hook the students into what they will be learning. One way teachers engage students is by selecting an anchoring phenomenon and essential questions to help drive their instruction. The Exploration stage is where inquiry should take root in the learning cycle. The teacher should not do any direct instruction, but instead the teacher is viewed more as a consultant that creates and fosters activities where the students perform hands-on investigations in the pre-determined phenomena (Gejda & LaRocco, 2006). The Exploration stage also provides opportunities for students with diverse backgrounds to share and expand on the understanding of the entire class (Llewellyn, 2013). This collaborative learning environment not only builds conceptual understanding of the content, but also improves social understanding. A study in an introductory physics course was administered with the goal to implement teaching strategies that help build that environment and increase students' motivation and metacognition. Student surveys were administered at the end of the semester, and the results showed a positive increase with feedback in classroom environment and support (Grandi et al., 2019). Also, in his article, Bobrowsky (2018) argues the importance of engaging students through a phenomenon-based learning approach. Instead of lecturing information to students, students are allowed to manipulate and play with materials in order to test and refine their understanding of what is causing the phenomenon. The Explanation stage is where students analyze and process the information gathered from the explore stage. This can be teacher-lead with a small group setting or as an entire class (Gejda & LaRocco, 2006). Here the teacher explains the concepts being explored and provides common language for all the students to use. The teacher uses the students' prior experiences to explain content and identify any misconceptions that were revealed during the engagement or exploration stages (Llewellyn, 2013). The Elaboration or Extension stage is one where the students are allowed to take what they have learned through the cycle so far, and then apply the knowledge to new and real-world phenomena (Gejda & LaRocco, 2006). This stage is meant to reinforce and deepen the conceptual understanding that the students have gained. Also, this stage creates a perfect setting for scientific argumentation to take root (Llewellyn, 2013). The last stage in the 5E Learning Cycle is Evaluation. Though this stage is meant to bring closure to a unit, formative assessments should be given throughout each stage of the cycle. Also, multiple types of summative assessments can be administered so that the teacher can gather the proper data for which standards are being evaluated on (Llewellyn, 2013) (Figure 1).

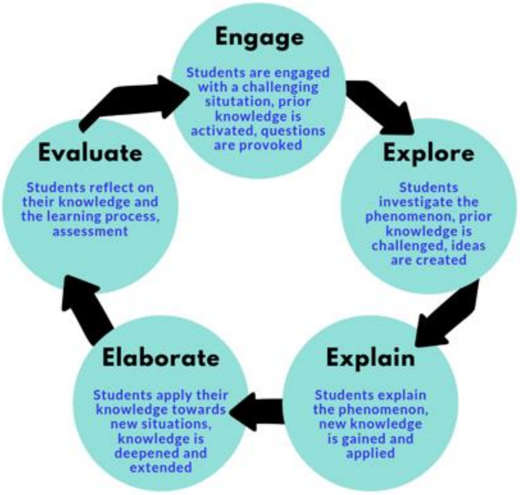

Figure 1. Overview of the 5E learning cycle model (Northern, 2019).

Semsettin Sahin and Meltem Baturay (2016) investigated the effects of achievement and satisfaction with students when they were taught using a 5E learning model in conjunction with WebQuest media. When the teacher was a facilitator of effectively scaffolded lessons, the benefits students saw ranged from improved engagement and critical thinking skills to improved foreign language speaking skills. The participants in the study were given mirrored pre- and post- achievement tests, as well as feedback surveys. The studies found that students who were taught using a 5E learning model with the use of WebQuest media scored higher on the post-tests than the control group. Also, a higher percentage of females found more satisfaction in learning with this approach, compared to their traditional curriculum.

Incorporating an Anchoring Phenomenon with Instruction

In order to make the 5E Learning Cycle an effective, engaging, and relevant method for delivering instruction to students, an anchoring phenomenon can be used to help drive each stage of the cycle. Students observing scientific phenomena in the classroom is not a radically new teaching method. Introducing phenomena through classroom demonstrations, labs, or videos are tools that every science teacher utilizes to engage students and help them better understand the content. However, an anchoring phenomenon is more complex and contains multiple scientific principles. A typical phenomenon could be introduced and understood by students over the course of just one class period, however, students would have to develop models and explanations throughout an entire unit to proficiently understand an anchoring phenomenon. (Windschitl et al., 2018). An anchoring phenomenon is effectively used to begin a unit, and serves as an idea of focus to help drive engagement and inquiry throughout various lessons in that unit (German, 2019). What all good anchoring events have in common is that they motivate students to explain what is going on by introducing complex and interesting real-world examples. Musallam (2017) refers to these events as “sparks” (p. 3). The reason why students get drawn into effectively picked phenomena is because those phenomena provide an information gap.

> “It’s an invisible cognitive barrier separating frustration and reward. On the surface, the emotional benefit we get from closing the information gap seems like a simple phenomenon, a fleeting feeling so intertwined into how we live our lives each day that we rarely take the time to contemplate or, even better leverage its unseen power” (Musallam, 2017, p. 12).

Also, using an anchoring event to drive a unit means that students no longer view content as something that is learned on a lesson-to-lesson basis, but rather activities that have a long-range view which tie in together to help solve a complex phenomenon. It makes more sense for students when phenomena are the motivating factors present in an inquiry-based learning cycle. Especially when the cycle itself is designed to facilitate students' application of content in various methods.

CHAPTER THREE

METHODOLOGY

Demographics

William Fremd High School (Fremd) is located in Palatine, IL, an area in the Northwest suburbs of Chicago. The school has a population of 2,583 students, where 50.8% are classified as White, 32.2% Asian, 10.3% Hispanic, and 3.1% Black (Students, n.d.). Academics at William Fremd High School are held in high regard amongst the students, faculty, and the community as well. We offer nine Advanced Placement (AP) or dual-credit science classes alone, and follow a school initiative which has a goal of having our seniors accumulate 15 college credits by the time they receive their high school diploma. Even though Illinois State Law only requires two years of science credits in order to graduate, the majority of Fremd students take a science class all four years, some even doubling up with science classes. In addition to the AP and dual-credit courses, juniors and seniors can also choose between nine different science electives that range in science subject matter and rigor. I currently teach four of the nine physics sections that our school has, along with three other experienced teachers that make up our physics professional learning team (PLT).

The students who are recommended to take physics their junior or senior year are almost all college-bound, and already have a record of success in their prior science courses. This allows us to set high expectations for the class, while also putting an emphasis on skills like collaboration and communication into most lessons. Of the 111 students I teach, 70 are female

(62%) and 41 male (38%), 14 of which (12.5%) qualify for special education services. Additionally, only 16 students (14%) are seniors, with the rest taking physics their junior year.

Treatment

This study was designed to explore the effects of student engagement and content understanding between teacher-led direct instruction, and NGSS- aligned content with inquiry-based learning which incorporates an anchoring phenomenon to drive instruction via the 5E Learning Cycle. Teacher-led direct instruction places the role of the teacher as the initial and main provider of content knowledge, where students are expected to soak up content and apply it in their individual or group practice. For example, last year when my district implemented new remote learning guidelines for students and staff, teacher-led direct instruction seemed to be the most effective way to deliver content after considering all of the limitations with teaching remotely. I taught our Energy Unit by providing information through the use of PowerPoint presentations, and the students followed along by filling out guided notes and completing guided example problems. In order to demonstrate their understanding of the content, students were then asked to complete problem sets either individually or online in breakout room groups. For example, after filling out notes during a presentation on different types of mechanical energies and conservation of energy, students were then asked to utilize their notes while completing energy transfer homework problems in breakout rooms. The unit also included a mid-unit quiz, and an exam at the end of the unit. Even with the added challenges and stresses that remote learning brings, a number of students seemed to excel learning from home. This observation further fueled my curiosity and drive to answer my study’s focus question, and see which teaching style lends itself most effective with my demographic of students. While this school year still had minimal pandemic-related mandates in place, it did give me the opportunity to conduct my action- research and compare the effectiveness between the two teaching styles.

All four of my current physics classes were taught in-person and went through the same non-treatment and treatment units together. My action- research began this past January when second semester started, and it ended in early April. During this study, my classes completed the following four units, each of which took around three weeks to complete: (a) Electrostatics, (b) Current Electricity, (c) Magnetism, and (d) Electromagnetic Induction. The Electrostatics and Magnetism Units were taught via direct instruction.

Similar to last year’s Energy Unit, I began both direct instruction units providing information with guided PowerPoint notes, and utilized demos as visual aids. However, before having students go off and work on problem sets in groups, I was able to include hands-on labs now that all students were in-person. For both direct instruction units, labs came after students had already completed specific content related notes, as a way for them to kinesthetically reaffirm their conceptual knowledge. For example, the Magnetism Unit started with two days of guided notes and demos where I provided content knowledge on the properties of magnetism. Some of the content included the differences between permanent, temporary, and electromagnets, and their common real-world applications. Once completing the introductory notes on magnetism, students were tasked with completing a stations lab the following day. Each station was tied to conceptual knowledge which students had already covered during the first two days of notes. Some stations included the exact equipment and procedure I modeled as class demos during teacher-led instruction the day before. Once the Magnetism Stations Lab was completed, students took a lab quiz as a way for me to formatively assess their knowledge.

Additionally, both direct instruction units included group work days for students to apply their conceptual understanding while completing various problem sets. All of the units in this study included mirrored pre- and post- unit exams.

Compared to teacher-led direct instruction where the teacher lectures information to students, an inquiry-based learning approach allows students to manipulate and play with materials in order to test and refine their own understanding of what is causing the phenomenon before the teacher provides explanations to the phenomena and proper terminology (Bobrowsky, 2018). The Current Electricity Unit and the Electromagnetic Induction Unit were both taught utilizing the 5E Learning Model to drive inquiry-based learning instruction. One of the major differences between these two teaching styles is how students were asked to conduct labs. With direct instruction, the students were already provided with the necessary conceptual knowledge to explain the phenomena they encountered in a lab setting. Ideally, there should not be surprising outcomes in lab data, and instead the labs serve as a way for students to reaffirm and solidify their prior understanding. With inquiry-based learning, students are tasked with drawing conceptual conclusions from data they gathered in labs, before they ever receive formal definitions or notes. For example, the Series and Parallel Circuits Lab during the Current Electricity Unit provided students with circuit-building lab supplies, and a goal for them to achieve. They were asked to construct and gather data on two different types of circuits, a circuit that lights up two bulbs with only one conducting path, and a circuit which split into two different paths, each containing a bulb, and comes back into one path before getting back to the battery. Students measured values of voltage and current at various locations for each circuit. Once they gathered the data, their goal was to analyze it and write what trends they noticed between the two different types of circuits. Afterwards, all the groups presented and we identified the similarities and differences in their trends together as a class. Without ever giving direct notes about the circuits beforehand, we were able to come up with the formal rules for how current and voltage vary in series and parallel circuits. This was the first time I tried to implement an inquiry-based learning approach that revolved around fundamental concepts for a unit, and I was elated when students reached the same conclusions that I would have normally presented during a lecture.

The 5E Learning Model is an effective method for developing and scaffolding lessons for inquiry-based learning units (Llewellyn, 2013). During the Engagement stage, teachers try to draw upon prior knowledge to hook the students into what they will be learning. The way I tried to engage students in this stage was by selecting an anchoring phenomenon and essential question to help drive their curiosity. For example, as students were walking into class on the first day of the last treatment unit, Electromagnetic Induction, I projected a video featuring the GravityLight in use, and played it on repeat. Without explaining, I then asked my students to write out what they observed and what questions they want answered (Appendix B). The GravityLight utilizes a generator to convert mechanical energy into electrical energy, in addition to other physics principles that allow it to operate. My classes had yet to learn anything about motors and generators or electromagnetic induction, but they did have conceptual understanding on circuits and electromagnetism from their prior units. The Exploration stage is where students conduct hands-on investigations in order to try and understand a phenomenon in question. I allowed students to collaborate together in groups, with three or four students per group, as they were tasked with trying to understand how a simple motor works. Even though the GravityLight doesn’t use an electrical motor to work, both motors and generators use similar materials and physics concepts to function. This was a full day activity where students had to collaborate and reason together while they constructed a working motor. During the Explanation phase, students start to analyze their observations and try to process what they experienced in the earlier stage of exploration. The following day, each group was tasked with identifying and describing as many physics concepts associated with the working motor as they could, and present their findings to the class afterwards. For example, each group wrote their initial observations and understandings of the phenomenon experienced in lab on their whiteboard, and used it as a visual aid as they presented their initial conclusions the class. Then all together, I wrote down common vocabulary and identified common conceptual definitions, and asked each group to redefine their understanding using the new language. In the Extension stage students try to apply their gained knowledge to a new situation. The Next Generation Science Standards (NGSS) also place a new emphasis on incorporating engineering practices in the curriculum. As a way to better align our content to NGSS standards, I had students conduct an engineering-based challenge lab where they had to create the most efficient homopolar motor they could. After their first build was complete, students had to find a way to effectively measure the performance of their motor and present their findings to the class. Once all groups received feedback following their presentations, they were asked to make adjustments to their designs and provide a justification for the changes. A prize was awarded for the group with the greatest change in their motor’s performance. I made it a point to revisit the GravityLight video at the end of each major assignment during the treatment unit. This is also where I revisited our anchoring phenomenon asking students to pull up what they originally wrote on the first day of our unit, and see if they can now answer some of the questions they once had. Students were also exposed to the connection between motors and generators by following similarly structured Explore and Explain activities. For example, instead of building a motor with a magnet and copper wiring, groups experienced a phenomenon of electromagnetic induction by dropping a magnet down a copper pipe. Each group was able to interact with different generator demos, and then made similar whiteboard presentations as they tried to explain the phenomenon they experienced. These various activities, all of which were structured following the 5E Learning Model, allowed students to discover the principles behind electromagnetic induction without me ever directly lecturing the content beforehand. The Evaluation stage is the summative assessment for the unit, which featured a mirrored post-test.

Data Collection and Analysis Strategies

In order to compare the students' conceptual understanding and content knowledge between the two different teaching methods, a multiple-choice pre- test was administered at the start of each treatment and nontreatment unit, followed by a mirrored post-test at the end of the unit. Analysis of the assessment data consisted of calculating normalized gains for each student, along with a paired t-test to see how significant the differences were between the groups and their pre- and post-test results. Multiple choice lab quizzes were also administered following the completion of each unit's major lab. The mean and overall letter grade distribution of these scores were analyzed and compared between groups. Additionally, classroom assessment techniques (CATs) were used throughout the units as regular formative assessments. Claim-Evidence-Reasoning sheets and muddiest point CATs were regularly administered as exit slips and analyzed for common themes and trends.

Student engagement was directly observed by my student intern during the magnetism unit, taught with direct instruction, and during the electromagnetic induction unit, taught using the 5E learning model. An engagement tally sheet was used to collect data for on-task and off-task behavior as a way to compare the engagement rate of students between the two different teaching methods (Appendix C). Data was collected two different times for each unit during my eighth period class. The observer was asked to identify, to the best of their ability, which students were demonstrating off-task behaviors every five minutes during the lesson. If a student was demonstrating an off-task behavior during the tally interval, the observer would mark a tally next to their name and time, however, students demonstrating on-task behavior would not receive a tally during that particular interval. Once all of the observations were completed, data between the two units was tallied and analyzed to see how many students were demonstrating on-task behavior throughout the length of a lesson.

As a way to better understand the effects on student engagement and attitude towards science when incorporating an anchoring phenomenon to drive instruction via the 5E Learning Cycle, a Test of Science-Related Attitudes (TOSRA) survey was administered to the treatment group (Appendix D). The survey consisted of 70 Likert-type questions that address seven different science-related attitude scales: (a) Social Implications of Science, (b) Normality of Scientists, (c) Attitude to Scientific Inquiry, (d) Adoption of Scientific Attitudes, (e) Enjoyment of Science Lessons, (f) Leisure Interest in Science, and (g) Career Interest in Science (Fraser, 1981). The same survey was given once before the treatment started, and once after the treatment ended. After using TOSRA’s scoring guide, data was analyzed by calculating the mean score and normalized gains for each of the seven TOSRA. The pre- and post- treatment survey results were compared in order to see what effects teaching via the 5E Learning Cycle might have on my students' science-related attitudes.

Student interviews were conducted at the end of the treatment as a way to better understand the student experience of learning through the 5E Learning Cycle (Appendix E). While all students had the option to fill out the interview form as a free response survey, six students in each class were selected to be interviewed. Of those six students, two had above average semester grades, two had average, and two had below average semester grades. The interview's free response questions were centered around asking students how they feel they best learn, and which activities during treatment were beneficial for their learning experience. These statements helped to provide context to the quantitative data and graphs.

Table 1. Data Triangulation Matrix.

Research Questions	Data Source #1	Data Source #2	Data Source #3
How does the incorporation of an anchoring phenomenon to drive instruction via the 5E Learning Cycle affect student growth	Pre- and Post-Tests	Lab Quiz Results	Formative Assessments via CATs
What affect does the incorporation of an anchoring phenomenon to drive instruction via the 5E Learning Cycle have on student engagement?	Engagement Tally Sheet	Student Surveys and Interviews	
How does the incorporation of an anchoring phenomenon to drive instruction via the 5E Learning Cycle affect students' attitudes toward science?	TOSRA Survey	Student Surveys and Interviews	

CHAPTER FOUR

DATA ANALYSIS

Results

The results from the Electromagnetic Induction Unit Pre- and Post- Tests, a treatment unit which incorporated an anchoring phenomenon to drive instruction via the 5E Learning Cycle, indicated the highest post- test mean score at 91% and highest average normalized gain value of 0.86 (*N*=111). Hake (1998) states that a normalized gain of 0.7 or greater is considered a high gain, while a normalized gain of 0.3 or less is considered a low gain. This unit also produced the largest high gain percentage with 91.5% of students earning a gain value greater than 0.7, while only 1 student earned a low gain value lower than 0.3 (*N*=106). The growth was observed across all student groups, with only 4% of students scoring lower than a 70% on the post- test. In addition, a paired t-test produced a p value less than 0.0001, which indicates that the data is significant since the p value is less than 0.05 (Figure 2) (Table 2).

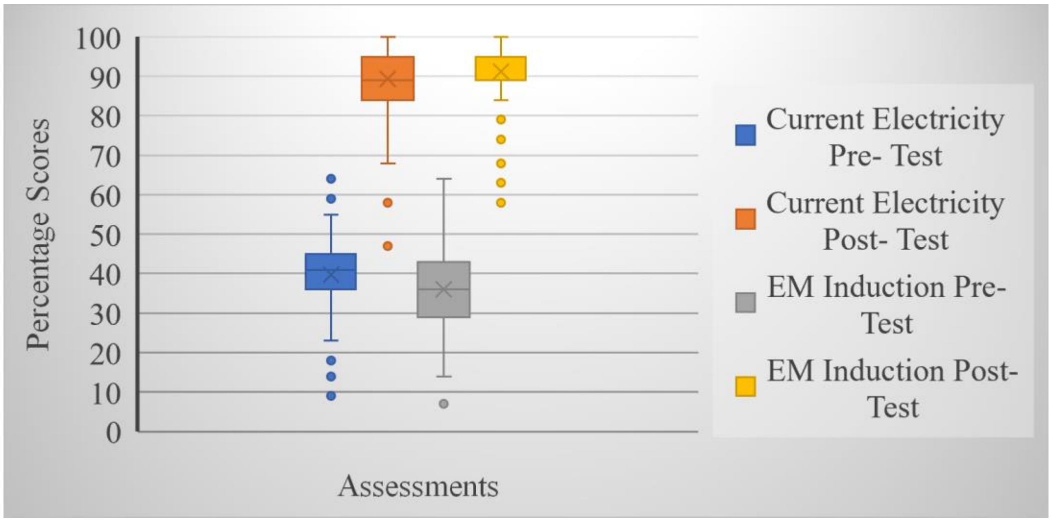

Figure 2. Pre- and post- test scores for units taught via the 5E Learning Cycle, (*N*=111).

Table 2. Pre- and post- unit normalized gain values.

Teaching Method	Unit	N	Normalized Gain
Direct Instruction	Electrostatics	101	0.74
Direct Instruction	Magnetism	102	0.75
5E Learning Cycle	Current Electricity	105	0.82
5E Learning Cycle	Electromagnetic Induction	107	0.86

After comparing assessment data between treatment and non-treatment groups, the units taught via teacher- led direct instruction produced lower averages and gains than the units taught utilizing the 5E Learning Cycle. The Electrostatics unit post-test mean was 84.6% with a median score of 86%. The group averaged a high normalized gain of 0.74, with 70% of total participants earning a high gain of 0.7 or greater, and 26% of total participants earning a medium gain between 0.3 and 0.7, and 4% earning a low gain of 0.3 or lower (*N*=101). The Magnetism unit post-test mean was 86.9% with a median score of 87%. The group averaged a high normalized gain of 0.75, with 67% of total participants earning a high gain, and 28% earning a medium gain, and 5% earning a low gain (*N*=102). The other unit taught using the 5E Learning Cycle was Current Electricity, which produced an average post- test score of 89%. This group averaged a high normalized gain of 0.82, with 82% of total participants earning a high gain, 17% earning a medium gain, and 1% earning a low gain (*N*=105). Additionally, post-lab quiz scores between the two groups followed a similar trend of unit test score distribution. The non-treatment lab, Magnetism Stations Lab, had 26.8% of students score below a 70% on the lab quiz, while only 12.7% of students scored below that during the treatment lab quiz, Series and Parallel Circuits Lab (Figure 3) (Table 2).

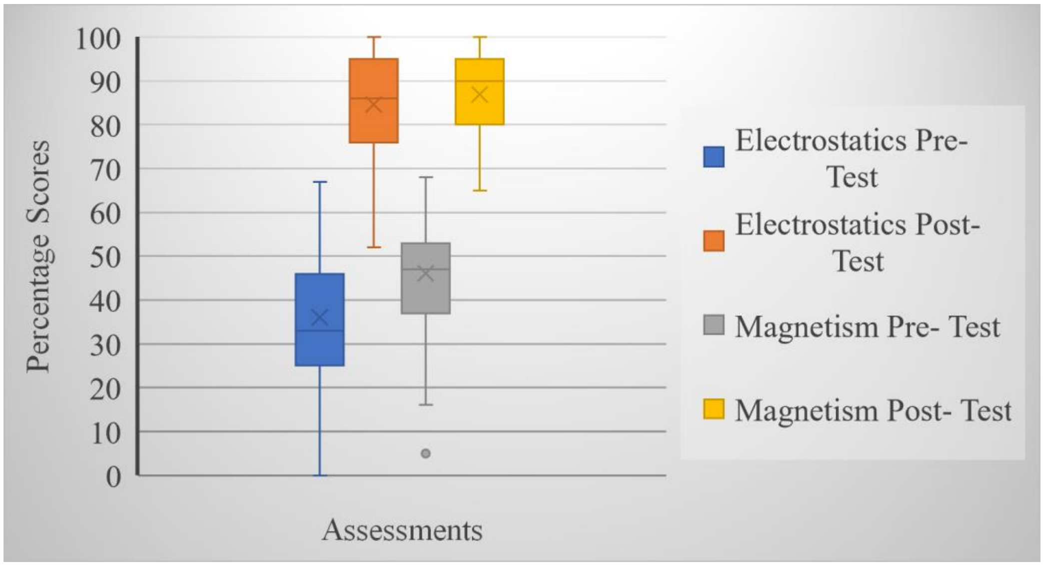

Figure 3. Pre- and post- test scores for units taught via direct instruction, (*N*=111).

Student engagement was observed for the same class between multiple non-treatment and treatment lessons, where a tally sheet helped track how many students were demonstrating off-task behavior every five minutes throughout a lesson (*n*=28). A lecture day was observed during the direct instruction led Magnetism Unit, where new content was presented with the help of a PowerPoint presentation and demos. Engagement steadily decreased during the first 20 minutes of the lesson, before the students got a three-minute break. There was a sudden increase after the break, but the steady decline continued until the students were given an exit slip for the last five minutes of class. When asked in a student interview to describe a moment when they did not feel engaged in class, one student replied “I didn’t feel engaged taking notes because I would not have much of a chance to participate.” The treatment group was observed during an Extension activity, where the students were tasked to try and engineer the most efficient motor from a set list of lab materials. Students were also asked to relate what they learned during the lab to show it might apply with understanding the anchoring phenomenon, the GravityLight. This activity saw a higher average of students engaged throughout the lesson, however, engagement did slightly decrease during the beginning stages of the engineering process. One student wrote "I did not like the motors lab. It was so hard to get it to work and I got frustrated because of it" (Figure 4).

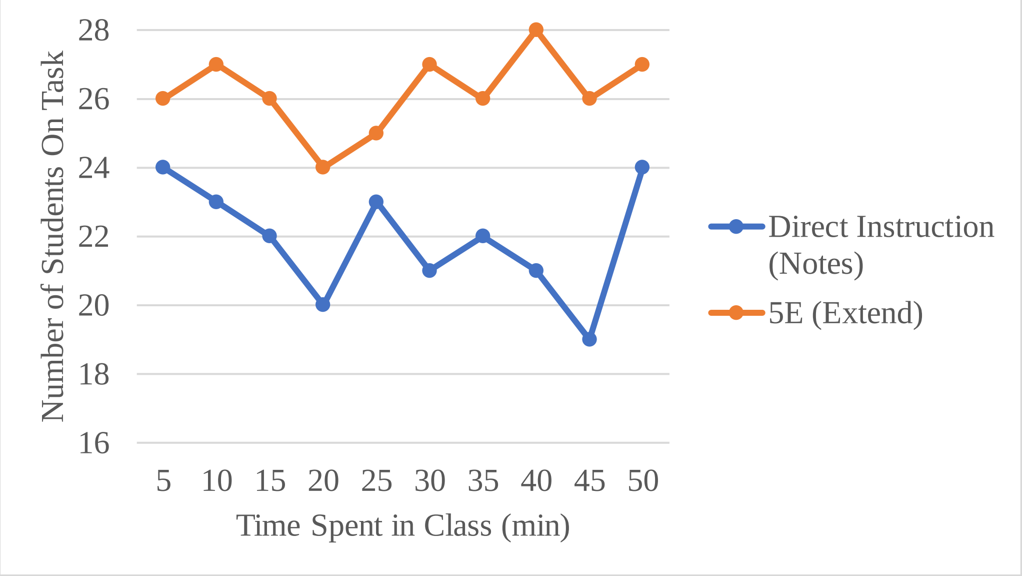

Figure 4. Student engagement tally throughout lesson, (*n*=28).

The second set of engagement tally data took place during a 25-minute lab activity. Like before, the same class was observed during both treatment and non-treatment units (*n*=28). The direct instruction unit utilized a Magnetism Stations Lab, where each station related to content that was already covered beforehand during lecture. Students were observed to be less engaged during the beginning of the activity, but engagement increased as it got closer to submitting their work at the end of the activity. One student wrote, "I didn't really like the magnets lab because I already knew what was going to happen." The treatment unit utilized a lab during the Explore stage of the 5E cycle. Each group was given the same simple motor, and were tasked with trying to relate their prior knowledge to understanding how it works. They also utilized whiteboards to help model their conclusions from the activity. The treatment unit averaged more student engagement; however, the data did decline during the last five minutes of the activity as some groups finished early (Figure 5) (Figure 6).

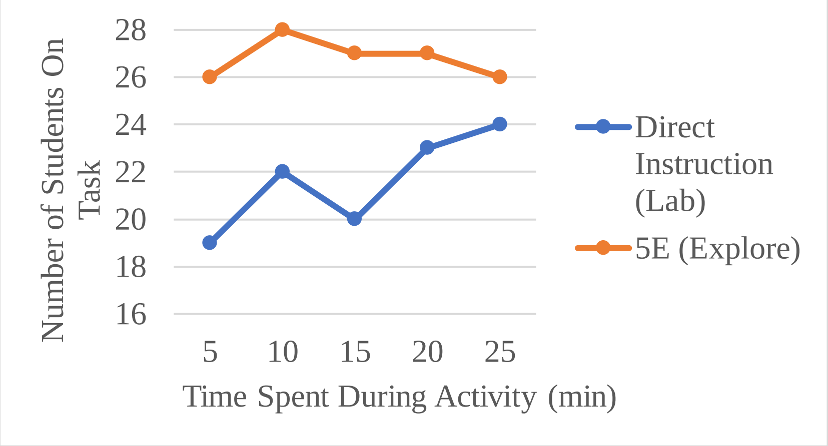

Figure 5. Student engagement tally throughout lab activity, (*n*=28).

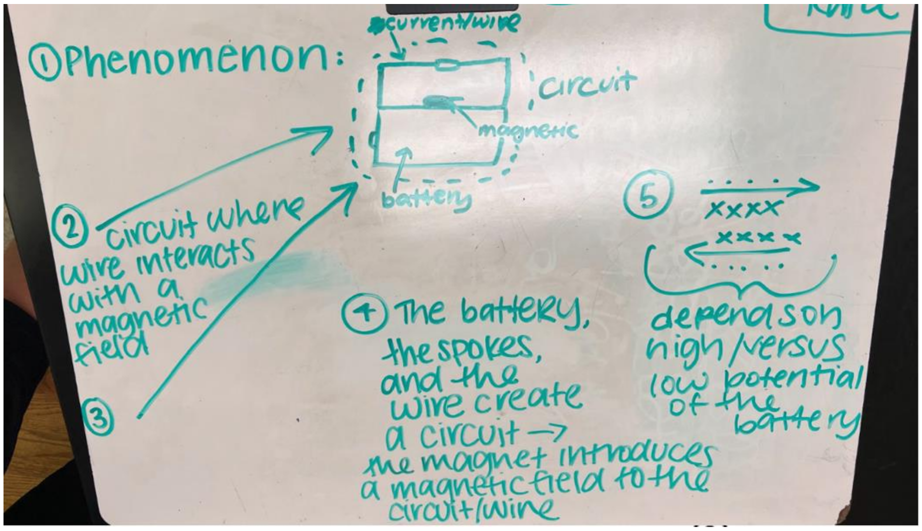

Figure 6. Example of student produced work during 5E lab activity.

The Test of Science- Related Attitudes (TOSRA) survey, a pre- and post- Likert-type survey, was administered to collect data on how the students' attitudes towards science related topics were affected throughout the research process. Data from the TOSRA survey was grouped into each of the specific science attitudes, and average scores for pre- and post- treatment data was calculated (*n*=88). The data shows a general increase in almost all of the sections, however, the changes are mostly minimal. The largest increase from pre- to post- survey data showed a 4.41-point increase with students and their attitude toward science related inquiry. After completing all post- treatment interviews (*n*=24), responses showed that 89% of students with below average grades felt that inquiry-based learning was their preferred instructional style. One student wrote, “Inquiry based instruction was better because it had more hands on activities which helped me stay focused.” Comparatively, 62% of students with above average grades preferred inquiry-based instruction over direct instruction. One student said, “I prefer to get the content knowledge ahead of time, because that way I don’t feel lost during the labs and I know I’m doing the correct thing” (Figure 7).

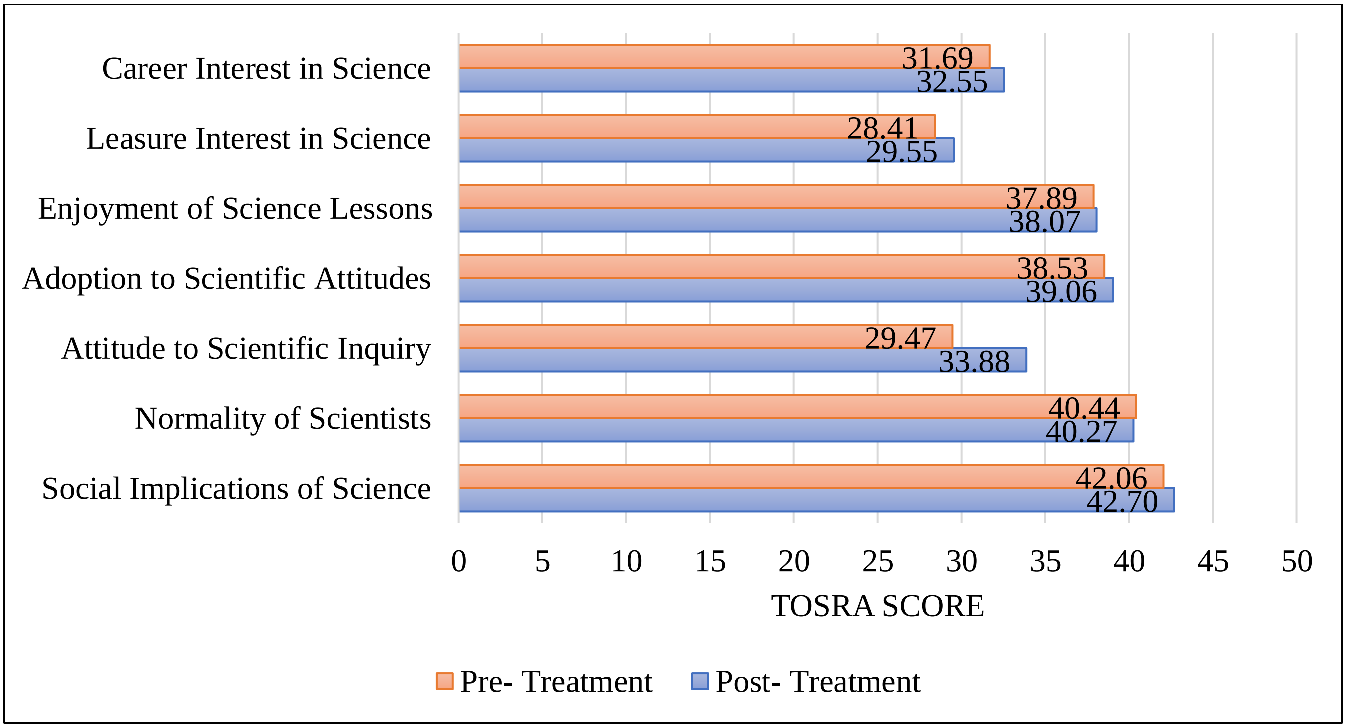

Figure 7. Pre- and post- treatment calculated means for each section in the TOSRA survey, (*n*=88).

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

The goal of this action research was to determine if student performance and engagement would increase if students completed a unit that utilized an anchoring phenomenon to help drive instruction via the 5E Learning Cycle, compared to a teacher- led direct instruction approach. In order to draw reasonable conclusions from the data, I conducted the action research over the course of four units, two of which were treatment units. This was meant to avoid the possibility of content rigor being a determining factor in assessment scores. The data gathered from pre- and post- assessments, lab quizzes, surveys, and student interviews showed that a 5E Learning Cycle inquiry-based learning approach combined with an anchoring phenomenon helped to produce higher scores, growth, and engagement amongst students. The last treatment unit, Electromagnetic Induction, produced the highest test average at 91%. Additionally, this unit also had the highest normalized gain of 0.86, with the most students achieving a high gain. I believe one of the main reasons for this trend is the way hands-on activities are scaffolded all throughout the treatment units. The kinesthetic learning approach gives students the ability to manipulate and test the science for themselves, which helped them to solidify and reaffirm their content knowledge. Additionally, group presentations during the explain phase helped to point out individual misconceptions that would have otherwise gone unaddressed in a teacher-led setting.

From the observations, interviews, and surveys it became obvious that student engagement increased during the treatment units. The contrast in assessment scores between each learning style could also be related to the engagement of students during those lessons. The engagement tally sheet clearly shows just how quickly students can lose interest when content is presented through only lecture, and how well engagement is sustained throughout hands-on inquiry activities. The lab quiz results also help to provide context. The self-motivated, above average students in my college-prep physics classes will typically have success regardless of how the content is presented to them. However, for the below average to average students, engagement in the content matter directly corresponds to classroom success. The fact that over twice as many students earned below a C on their lab quiz during the non-treatment units indicates that there was less engagement and content retention during direct instruction. Especially when considering that those students were already exposed to the content and what the expected results should be before conducting the lab themselves. Outside of measurable data, I could easily sense the difference in the energy that students had during the 5E units. There were noticeably more content related discussions when students were given the opportunity to collaborate in groups, and a more positive energy in the classroom as students got to discover the phenomenon themselves.

The incorporation of an anchoring phenomenon to drive instruction via the 5E Learning Cycle affected students' attitudes toward science in a generally positive way. The pre- and post-Likert-type TOSRA surveys helped highlight the gradual increase in their average scores for each specific attitude, however, there was not enough change to draw significant conclusions for all sections in the survey. The largest positive increase in attitude was towards scientific inquiry at 4.41 points. However, I only incorporated an anchoring phenomenon for one of the four units during this action research. More data is needed for me to draw more definitive conclusions about how an anchoring phenomenon specifically helped change science related attitudes.

Value of the Study and Consideration for Future Research

After teaching the same course for a few years, it became obvious that the pace and style which we covered the content in was not in the best interest for sustained student success. Students excelled at memorizing their notes to complete homework and assessments, however, they struggled with understanding how to apply prior knowledge to new situations, or to see how concepts connected from one unit to the next. Since inquiry was not prioritized, science-based discussions were typically surface level, and I wanted to cultivate a classroom culture that promoted more meaningful student engagement with the content. Even though assessment data showed overall success, we were basically teaching students how to be really good at memorizing facts and regurgitating them back during assessments. After starting this program, I knew this would be the perfect opportunity and motivation to start revamping our Physics 432 curriculum so that it focused more on students learning science by actually doing science.

Creating a more student-led learning approach via the 5E Learning Cycle helped shift the focus towards allowing students to engineer and test their own experiments as a way to develop evidence-based conclusions. Additionally, the use of an anchoring phenomenon to drive instruction has facilitated in promoting sustained interest and content engagement from the students. Furthermore, the shift towards a collaborative learning environment has also helped create a more positive classroom culture, where students have embraced learning from their mistakes and from each other. The post-unit survey feedback has indicated that students preferred the inquiry and modeling approach, because it allowed them more opportunities to work through and reflect on their conceptual knowledge and understanding with their lab groups.

After reflecting on these past few months, the new action research I would like to consider for the future would be the incorporation of a treatment and non-treatment group during the same unit. Testing how the different teaching methods relate to one another, without content rigor becoming a factor, might lead to more conclusive results. Additionally, I would like test how utilizing an anchoring phenomenon to drive instruction affects student engagement between groups learning the same unit through the 5E Learning Cycle. This way I would be able to clearly identify if the anchoring phenomenon was the cause for student growth, and not the teaching method. Furthermore, I would include a Likert-type survey on lesson effectiveness after most lessons. The additional information would provide insight into what specific types of lessons students found to be most effective, and how lesson effectiveness correlates with overall student performance, engagement, and science-related attitudes.

Impact of Action Research on the Author

After observing positive results from the few early inquiry-based lessons I had developed my first two years in the program, I knew this was the way I wanted to approach all of my future lessons. The other teachers in my physics professional learning team (PLT) shared in my excitement to revamp the curriculum, and joined me while we attended a two-week summer workshop on Physics Modeling Instruction prior to this school year starting. Modeling Instruction is not a new curriculum, rather another way to conduct inquiry-based learning in the classroom. This workshop not only provided content knowledge about Modeling Instruction, but also allowed us to play the role of students and teachers throughout various mock lessons. These experiences reaffirmed our desire to change our physics curriculum, and Modeling Instruction became another tool I used to incorporate more student-centered lessons.

In order to promote student collaboration, we obtained class sets of large whiteboards to use throughout our units as a way for students to create and present visual representations of physics concepts. My goal was to incorporate a whiteboarding activity at least once every 1-2 weeks, and I am happy to say that I have kept up with that goal throughout this year, not just during the treatment units. These activities included creating and presenting graphical and mathematical models from lab data, describing and presenting content related phenomena, organizing prior knowledge to help describe and understand new concepts, and completing math and conceptual- based group challenge problems.

The presentation aspect that student-led whiteboarding provides has also served as a wonderful formative assessment tool for me to address common misconceptions that I may not have spotted earlier. When I notice that a group is either misunderstanding or not addressing major concepts, I can now easily draw comparisons from other student work as a way to guide the students to a better conclusion. Additionally, I have found it easier to identify what objectives I need to reteach by noticing if most of the groups are not correctly addressing major concepts.

As a way to measure student understanding and NGSS aligned engineering practices, we have also started to develop summative lab practicals that mirror the major inquiry-based labs that students complete at the start of each unit. The assessment results from these practicals have shown positive student growth, and have even led to higher overall averages in the lab category of the gradebook compared to previous years teaching.

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APPENDICES

APPENDIX A

IRB APPROVAL

Dear Vasilij,

Thank you for your application. This email acknowledges receipt of the request for IRB Review and serves as the Approval Letter for your research. Your new **IRB Exempt Protocol # is VA013122-EX**.

Study Title: **Anchoring Phenomenon and 5Es in High School Physics**

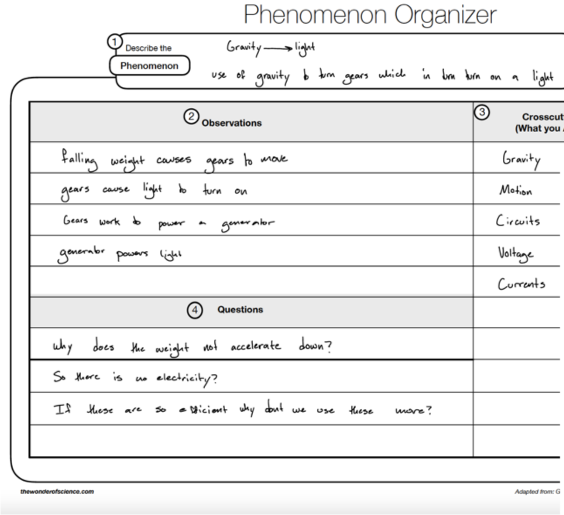
As the PI, it is your responsibility to facilitate subject understanding by informing subjects of all aspects of the project, providing an opportunity to ask questions, and describing risks and benefits of participation. Submit any new changes to the research protocol to the IRB via Amendment Form prior to implementing.

The research described in your submission is exempt from the requirement of additional review by the Institutional Review Board in accordance with 45 CFR 690.104(d). The specific paragraph which applies to your research is:

(1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

APPENDIX B

STUDENT EXAMPLE OF ANCHORING PHENOMENON ORGANIZER



Phenomenon Organizer

① Describe the **Phenomenon**

Gravity → light

use of gravity to turn gears which in turn turn on a light

② **Observations**	③ **Crosscutting Concept (What you Already Know)**
falling weight causes gears to move	Gravity
gears cause light to turn on	Motion
Gears work to power a generator	Circuits
generator powers light	Voltage
	Currents
④ **Questions**	
why does the weight not accelerate down?	
So there is no electricity?	
If these are so efficient why dont we use these more?	

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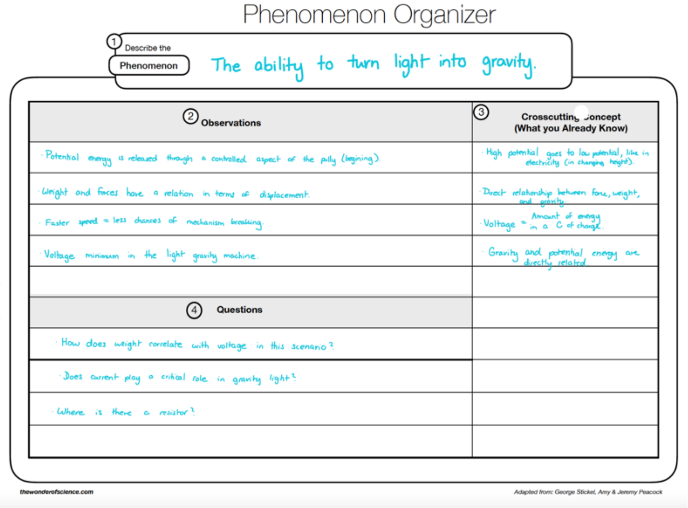
Adapted from: G



Phenomenon Organizer

① Describe the **Phenomenon**

The ability to turn light into gravity.

② **Observations**	③ **Crosscutting Concept (What you Already Know)**
· Potential energy is released through a controlled aspect of the pully (begining).	· High potential goes to low potential, like in electricity (in changing height).
· Weight and forces have a relation in terms of displacement.	· Direct relationship between force, weight, and gravity.
· Faster speed = less chances of mechanism breaking.	· Voltage = Amount of energy in a C of charge.
· Voltage minimum in the light gravity machine.	· Gravity and potential energy are directly related.
④ **Questions**	
· How does weight correlate with voltage in this scenario?	
· Does current play a critical role in gravity light?	
· Where is there a resistor?	

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Adapted from: George Stickel, Amy & Jeremy Peacock

APPENDIX C

TALLY FOR ENGAGEMENT

	Tally Chart for Off- Task Student Behavior During Class at Time Interval (min)									
Name	5	10	15	20	25	30	35	40	45	50
1										
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28										

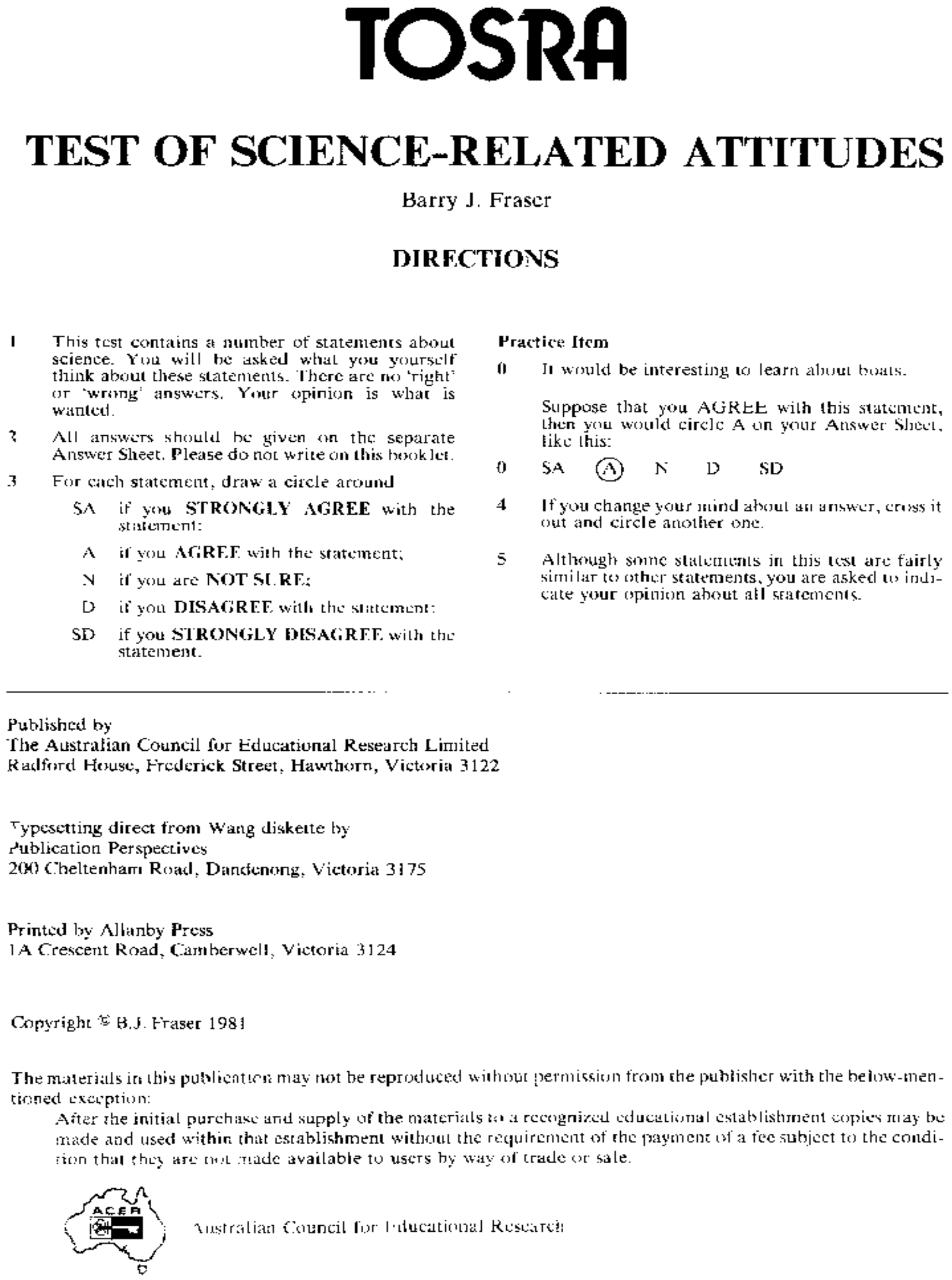
Participation in this research is voluntary and participation or non- participation will not affect a student's grade or class standing in any way.

Off- Task Behavior Examples

Improper or unrelated use of iPad during academic time, Talking with others about non-academic matters, Sleeping or staring off into space, Not participating in class activity/objective, Causing a disruption, Using cell phone during instructional time, Improper use of lab/classroom equipment.

APPENDIX D

TEST OF SCIENCE-RELATED ATTITUDES (TOSRA) SURVEY



TOSRA

TEST OF SCIENCE-RELATED ATTITUDES

Barry J. Fraser

DIRECTIONS

1 This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

2 All answers should be given on the separate Answer Sheet. Please do not write on this booklet.

3 For each statement, draw a circle around

- SA if you **STRONGLY AGREE** with the statement;
- A if you **AGREE** with the statement;
- N if you are **NOT SURE**;
- D if you **DISAGREE** with the statement;
- SD if you **STRONGLY DISAGREE** with the statement.

Practice Item

0 It would be interesting to learn about boats.

Suppose that you AGREE with this statement, then you would circle A on your Answer Sheet, like this:

0 SA [✓ A] N D SD

4 If you change your mind about an answer, cross it out and circle another one.

5 Although some statements in this test are fairly similar to other statements, you are asked to indicate your opinion about all statements.

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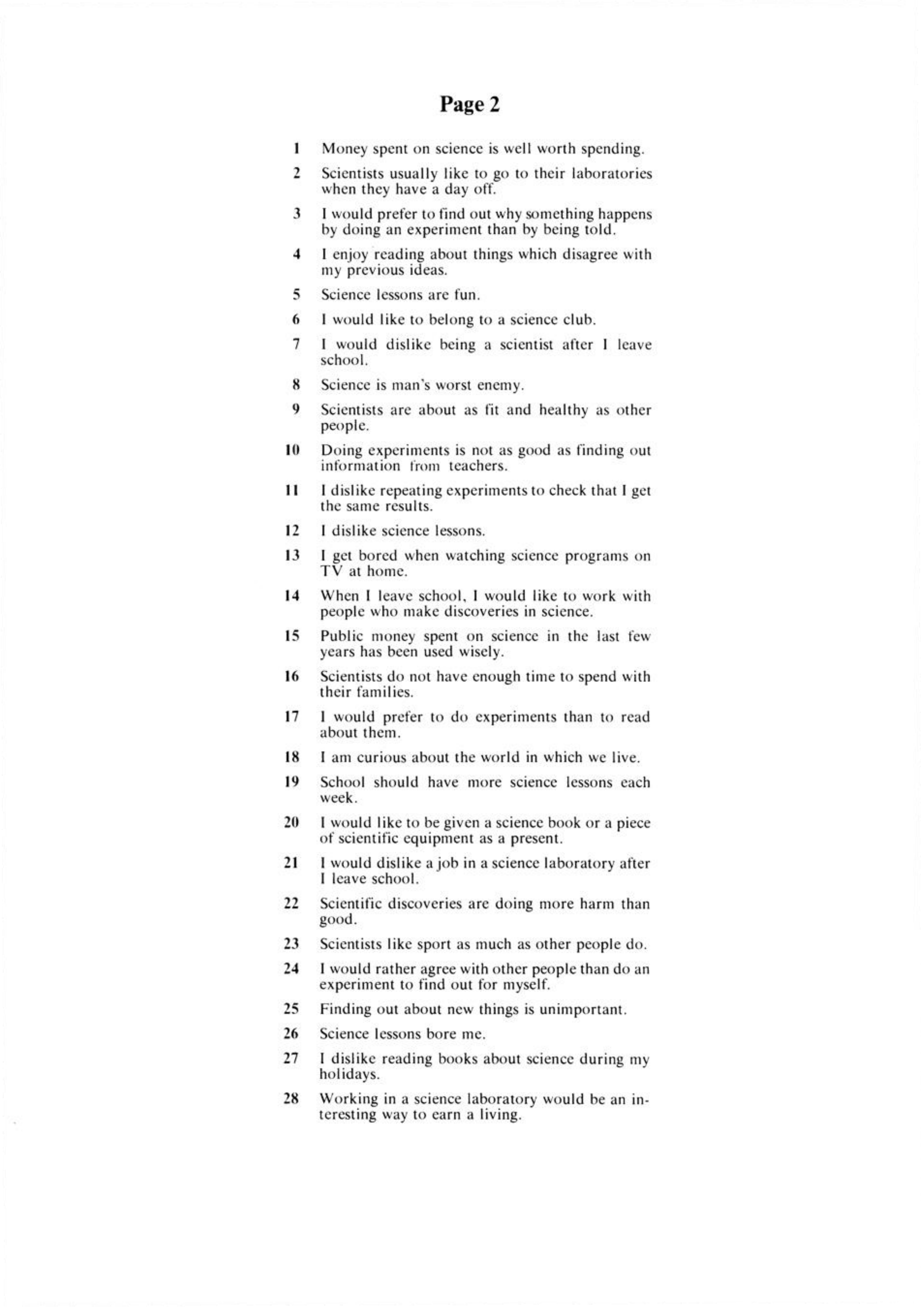

Page 2

1 Money spent on science is well worth spending.

2 Scientists usually like to go to their laboratories when they have a day off.

3 I would prefer to find out why something happens by doing an experiment than by being told.

4 I enjoy reading about things which disagree with my previous ideas.

5 Science lessons are fun.

6 I would like to belong to a science club.

7 I would dislike being a scientist after I leave school.

8 Science is man's worst enemy.

9 Scientists are about as fit and healthy as other people.

10 Doing experiments is not as good as finding out information from teachers.

11 I dislike repeating experiments to check that I get the same results.

12 I dislike science lessons.

13 I get bored when watching science programs on TV at home.

14 When I leave school, I would like to work with people who make discoveries in science.

15 Public money spent on science in the last few years has been used wisely.

16 Scientists do not have enough time to spend with their families.

17 I would prefer to do experiments than to read about them.

18 I am curious about the world in which we live.

19 School should have more science lessons each week.

20 I would like to be given a science book or a piece of scientific equipment as a present.

21 I would dislike a job in a science laboratory after I leave school.

22 Scientific discoveries are doing more harm than good.

23 Scientists like sport as much as other people do.

24 I would rather agree with other people than do an experiment to find out for myself.

25 Finding out about new things is unimportant.

26 Science lessons bore me.

27 I dislike reading books about science during my holidays.

28 Working in a science laboratory would be an interesting way to earn a living.

Page 3

29 The government should spend more money on scientific research.

30 Scientists are less friendly than other people.

31 I would prefer to do my own experiments than to find out information from a teacher.

32 I like to listen to people whose opinions are different from mine.

33 Science is one of the most interesting school subjects.

34 I would like to do science experiments at home.

35 A career in science would be dull and boring.

36 Too many laboratories are being built at the expense of the rest of education.

37 Scientists can have a normal family life.

38 I would rather find out about things by asking an expert than by doing an experiment.

39 I find it boring to hear about new ideas.

40 Science lessons are a waste of time.

41 Talking to friends about science after school would be boring.

42 I would like to teach science when I leave school.

43 Science helps to make life better.

44 Scientists do not care about their working conditions.

45 I would rather solve a problem by doing an experiment than be told the answer.

46 In science experiments, I like to use new methods which I have not used before.

47 I really enjoy going to science lessons.

48 I would enjoy having a job in a science laboratory during my school holidays.

49 A job as a scientist would be boring.

Page 4

50 This country is spending too much money on science.

51 Scientists are just as interested in art and music as other people are.

52 It is better to ask the teacher the answer than to find it out by doing experiments.

53 I am unwilling to change my ideas when evidence shows that the ideas are poor.

54 The material covered in science lessons is uninteresting.

55 Listening to talk about science on the radio would be boring.

56 A job as a scientist would be interesting.

57 Science can help to make the world a better place in the future.

58 Few scientists are happily married.

59 I would prefer to do an experiment on a topic than to read about it in science magazines.

60 In science experiments, I report unexpected results as well as expected ones.

61 I look forward to science lessons.

62 I would enjoy visiting a science museum at the weekend.

63 I would dislike becoming a scientist because it needs too much education.

64 Money used on scientific projects is wasted.

65 If you met a scientist, he would probably look like anyone else you might meet.

66 It is better to be told scientific facts than to find them out from experiments.

67 I dislike listening to other people's opinions.

68 I would enjoy school more if there were no science lessons.

69 I dislike reading newspaper articles about science.

70 I would like to be a scientist when I leave school.

Test of Science-Related Attitudes

Answer Sheet

Name ______________________________

School ____________________ Year/Class ____________

	Page 2						Page 3						Page 4				
	STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE		STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE		STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE
1	SA	A	N	D	SD	**29**	SA	A	N	D	SD	**50**	SA	A	N	D	SD
2	SA	A	N	D	SD	**30**	SA	A	N	D	SD	**51**	SA	A	N	D	SD
3	SA	A	N	D	SD	**31**	SA	A	N	D	SD	**52**	SA	A	N	D	SD
4	SA	A	N	D	SD	**32**	SA	A	N	D	SD	**53**	SA	A	N	D	SD
5	SA	A	N	D	SD	**33**	SA	A	N	D	SD	**54**	SA	A	N	D	SD
6	SA	A	N	D	SD	**34**	SA	A	N	D	SD	**55**	SA	A	N	D	SD
7	SA	A	N	D	SD	**35**	SA	A	N	D	SD	**56**	SA	A	N	D	SD
8	SA	A	N	D	SD	**36**	SA	A	N	D	SD	**57**	SA	A	N	D	SD
9	SA	A	N	D	SD	**37**	SA	A	N	D	SD	**58**	SA	A	N	D	SD
10	SA	A	N	D	SD	**38**	SA	A	N	D	SD	**59**	SA	A	N	D	SD
11	SA	A	N	D	SD	**39**	SA	A	N	D	SD	**60**	SA	A	N	D	SD
12	SA	A	N	D	SD	**40**	SA	A	N	D	SD	**61**	SA	A	N	D	SD
13	SA	A	N	D	SD	**41**	SA	A	N	D	SD	**62**	SA	A	N	D	SD
14	SA	A	N	D	SD	**42**	SA	A	N	D	SD	**63**	SA	A	N	D	SD
15	SA	A	N	D	SD	**43**	SA	A	N	D	SD	**64**	SA	A	N	D	SD
16	SA	A	N	D	SD	**44**	SA	A	N	D	SD	**65**	SA	A	N	D	SD
17	SA	A	N	D	SD	**45**	SA	A	N	D	SD	**66**	SA	A	N	D	SD
18	SA	A	N	D	SD	**46**	SA	A	N	D	SD	**67**	SA	A	N	D	SD
19	SA	A	N	D	SD	**47**	SA	A	N	D	SD	**68**	SA	A	N	D	SD
20	SA	A	N	D	SD	**48**	SA	A	N	D	SD	**69**	SA	A	N	D	SD
21	SA	A	N	D	SD	**49**	SA	A	N	D	SD	**70**	SA	A	N	D	SD
22	SA	A	N	D	SD												
23	SA	A	N	D	SD												
24	SA	A	N	D	SD												
25	SA	A	N	D	SD												
26	SA	A	N	D	SD												
27	SA	A	N	D	SD												
28	SA	A	N	D	SD												

For Teacher Use Only

S ____ N ____ I ____ A ____ E ____ L ____ C ____

APPENDIX E

INTERVIEW QUESTIONS

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

1. How do you learn best? Why do you think that is?
2. What did you like about the curriculum? Why?
3. What did you not like about the curriculum? Why?
4. Describe a moment when you felt engaged in the class. Why do you think that was?
5. Describe a moment when you did not feel engaged in the class. Why do you think that was?
6. Do you typically enjoy science classes? Why or why not.
7. Which teaching method did you prefer, direct instruction or inquiry-based learning?

   Why?
8. What do you not like about the other method?
9. Which activity was most helpful to your learning during this unit?
10. What skills did you learn or improve in while being in this class?
11. Is there anything else you'd like me to know about your experience in this class?