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Comparison between the Effectiveness of mySci and OpenSciEd Curricula on the Achievement and Attitudes of Eighth Grade Science Students

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Abstract

Educators have struggled with maintaining student engagement in science, especially as students transition from primary to middle school and upper grades (Vedder-Weiss & Fortus, 2012). A recent push in science education has been the adoption of the Next Generation Science Standards (NGSS), released in 2013, whose development was guided by *A K-12 Framework for Science Education* (NGSS Lead States, 2013). As a result, more educators have been incorporating curricula that require students to ascertain *disciplinary core ideas* using lenses of *cross cutting concepts* while engaged in *science and engineering practices*; the three dimensions of NGSS performance expectations (PE) also known as three-dimensional learning when in practice. Two curricula, mySci (Washington University in St. Louis Institute for School Partnership, 2020) and OpenSciEd (OpenSciEd, 2021), were compared in terms of student academic achievement and attitudes towards science. The research questions were: (1) To what extent is there a difference between achievement in science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by end of unit assessment scores? (2) To what extent is the difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by My Attitudes Toward Science (MATS) survey (Hillman et al., 2016)?

Keywords: 5E curriculum, storyline curriculum, attitudes toward science, science achievement, social constructivist theory, expectancy-value theory

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Nina Blanton ~ Last but not least, giving honor to God who has carried me through this process. Eternally grateful.

Dedications

I would like to dedicate this dissertation in loving memory of my brother, Sterling, my grandson, Taylin and my forever partner, Jerry. To my family and friends for their unwavering support. Special dedication to my daughter Naiya and my mother Bethany, They are truly the wind beneath my wings. ~ Nina

I would like to dedicate this dissertation to my amazing child, Parker, and my family for their unrelenting support during this process. ~ Nicole

Chapter 1

Introduction

Educators have struggled with maintaining student engagement in science, especially as students transition from primary to middle school and upper grades (Vedder-Weiss & Fortus, 2012). A recent push in science education has been the adoption of the Next Generation Science Standards (NGSS), released in 2013, whose development was guided by *A K-12 Framework for Science Education* (NGSS Lead States, 2013). As a result, more educators have been incorporating curricula that require students to ascertain *disciplinary core ideas* using lenses of *cross cutting concepts* while engaged in *science and engineering practices*; the three dimensions of NGSS performance expectations also known as three-dimensional learning when in practice. Two curricula, mySci (Washington University in St. Louis Institute for School Partnership, 2019) and OpenSciEd (OpenSciEd, 2021), were compared in terms of student achievement and attitudes toward science.

Background

When thinking about the importance of maintaining student's positive attitudes toward science throughout their K-12 educational experience, we need to consider the future implications of decreased student interest. Students who lose interest in science have a tendency to enroll in non-science coursework as they move from middle to upper grades or pursue higher education (Gibson & Chase, 2002; Wang, et al., 2015). This could impact the future of the U.S. workforce in the coming years due to the increased demands for scientifically literate and skilled workers.

Scientific Literacy in the United States Workforce

According to the U. S. Census Bureau, almost 11 million Americans are working in a STEM-related field (2019). The projected growth for STEM-related fields in the next ten years is around 10%, compared to almost 4% in non-STEM fields (Okrent & Burke, 2021). The STEM workforce consists of those in what may be thought of as more traditional areas, like computer technologies and medicine, but another, expanded, sector of STEM fields are those workers making up the skilled trades, such as construction (Okrent & Burke, 2021). The expanded definition of STEM-related fields to include skilled trade workers, highlights the importance of developing students that are scientifically literate once they graduate from high school. The development of scientific literacy should be a focus of the entire K-12 educational system and not just something left for middle and upper level educators. With the introduction of the Next Generation Science Standards (NGSS) in 2013 and Every Student Succeeds Act (ESSA) in 2015, the importance of K-12 science education was pushed to the forefront as students were required to be tested in science at least three times during their K-12 education (NGSS Lead States, 2013; U.S. Department of Education, n.d.-a; U.S. Department of Education, n.d.-b).

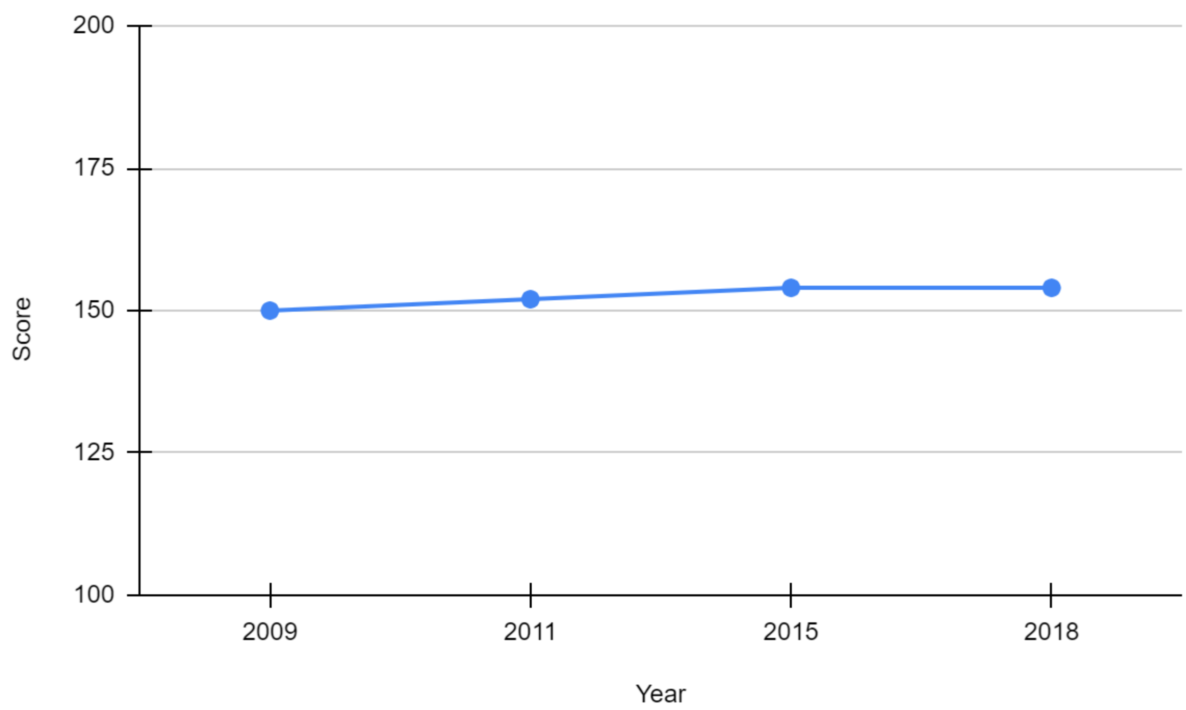
STEM Education in the United States

One way to increase scientific literacy of students and maintain student interest is the implementation of inquiry-based curriculum in schools. The 2018 National Survey of Science and Mathematics Education (NSSME+) found that 77% of middle school classes focused on students understanding science concepts using traditional teaching methodology (Smith, 2020). Educators are engaging their students the least in those that best support inquiry, as called for by the NGSS. NSSME+ respondents were asked about which instructional activities took place during a typical school week. 92% of educators reported that they “explain science ideas to the whole class” followed by “engage the whole class in discussions” with only 31% of the time using problem-based learning activities (Smith, 2020, p. 9). Instructional practices indicated by teachers that are more traditional versus inquiry-based may help to explain student scores on the National Assessment of Educational Progress (NAEP).

The most recent NAEP was conducted in 2019 and administered to 31,400 eighth grade students in 1,070 schools across the United States (National Center for Education Statistics, 2021). Student scores in science remained the same in 2019 compared to 2015 scores, but differed significantly compared to scores in 2009 and 2011 as shown in Figure 1.1 (National Center for Education Statistics, 2021).

Figure 1.1

Eighth Grade NAEP Science Scores, 2009 - 2018



Note. Eighth grade scores on NAEP science scores beginning in 2009. Scores prior to 2009 are not included because the test was realigned to fit new national standards. NAEP science scores are scaled from 0-300. In order to show differences in eighth grade scores, a smaller range of scores are presented. Data from National Center for Education Statistics (2021).

Although there is improvement, only 35% of students in eighth grade scored at or above NAEP Proficient (National Center for Education Statistics, 2021). This means that over 20,000 students were not proficient in their science content knowledge and for the bottom 10th percentile there was a decrease across all three content areas (life science, physical science, and Earth and space science) (National Center for Education Statistics, 2021). Students were also asked about how they receive their science instruction. While studies have shown that inquiry-based instructional strategies positively impact student academic achievement (Gibson & Chase, 2002; Wang, et al., 2015), only 42% of students reported engaging in inquiry-based activities (National Center for Education Statistics, 2021).

STEM-Related Careers in the United States

In 2018, 3.2 million students graduated from college (National Center for Education Statistics, 2019b). About 1 million of those students entered the workforce, while 2.2 million were enrolled in either 2- or 4-year higher education institutions (National Center for Education Statistics, 2019b). College enrollment in 2018 was a little more than 20 million students, composed of those attending 2- or 4-year institutions and certificate programs (National Center for Education Statistics, 2019a). Of those enrolled, the number of students earning degrees and certificates in STEM-related fields has increased from around 600,000 to over 700,000 (National Center for Education Statistics, 2019a).

The National Academies of Sciences, Engineering, and Medicine (2017) report, *Building America's Skilled Technical Workforce*, found that the majority of skilled positions in the workforce do not require a bachelor's degree. This points to the importance of preparing the workforce during their K-12 educational experience. Because of this need, the report examined the role of education in developing the skills needed for the future U.S. workforce. One facet of the ESSA is to improve STEM education (U.S. Department of Education, n.d-a). Under Title IV of ESSA, a portion of the $1.65 billion grant program is allocated to programs that enhance STEM education (National Science Teaching Association, n.d.). STEM activities that would qualify for assistance using the grant funding includes expansion of high-quality STEM courses (National Science Teaching Association, n.d.). The grant funding could be used to help districts implement new curriculum which would support STEM education in the district. By incorporating a new curriculum that supports students' STEM education, the K-12 educational system would potentially graduate students that are better suited for the STEM-related field workforce.

Problem

Building a workforce that is scientifically literate and skilled should be an essential focus of K-12 science education. With the expansion of identification of STEM-related fields, more and more workers need basic levels of scientific understanding for their careers. A way to ensure that the K-12 educational system is developing those basic levels of scientific understanding, as identified by NGSS standards, is to incorporate curriculum specifically aligned to NGSS standards. When deciding upon the curriculum a school district adopts, they also should consider how students are experiencing the curriculum, passive or active learning, and the potential impacts of student experience. Curricular choices which would positively impact both student achievement and attitudes toward science should be considered. Identifying and implementing an inquiry-based curriculum program which is aligned to the NGSS standards, and incorporates opportunities for students to engage in developing '21st century skills,' is an overwhelming task for many school districts. There has been a delayed implementation of NGSS-aligned curriculum because the development process is more nuanced than development processes of prior curriculum due to the three-dimensional nature of instruction called for by the standards. By comparing two inquiry-based curricula programs that are aligned to the NGSS but are inherently different in the way students experience coherence, we will be able to provide guidance in the implementation of a program which will directly impact both student learning and attitudes toward science.

Declining Student Attitudes Toward Science

The type of learning called for in the NGSS standards is three-dimensional in nature, requiring students to engage in science and engineering practices using lenses of crosscutting concepts as they work collectively to make sense of phenomena building their science disciplinary core knowledge. Students in a classroom that is three-dimensional should be active learners, rather than passive learners as seen in a traditional classroom. One approach to implement three-dimensional learning in a science classroom is to use an inquiry-based curriculum.

Inquiry-based instructional practices and student engagement with inquiry became a focus for educators with the introduction of the National Science Education Standards (NSES) introduced in 1996 (Bybee, 2006). The focus on inquiry-based instruction is also at the forefront of the NGSS, introduced in 2013. Much research has been done to identify the impacts of traditional and inquiry-based science instructional practices in student academic achievement. Traditional instruction, references lecture-based instruction with confirmation laboratory investigations. Inquiry-based instruction refers to an active learning approach where student actions build scientific content knowledge. In general, much of the research points toward increased student academic achievement in inquiry-based classrooms (Anderson, 2002; Aktamis, et al., 2016; Minner, et al., 2010), while some research has found a negative impact on student achievement (Cairns & Areepattamannil, 2017; Jiang & McComas, 2015), and others say it depends on the environment (Mostafa, et al., 2018).

Theoretical Frameworks

Two theoretical frameworks have been identified to guide the development of the investigation into curricula impacts on student achievement in science and attitudes toward science. Social constructivist theory underlines the development of both mySci and OpenSciEd curricula. Both use an approach that relies on students being active participants in their learning (OpenSciEd, 2019; Washington University in St. Louis Institute for School Partnership, 2020). Expectancy-value theory helps to provide the framework to understand the impacts of curriculum on student attitudes toward science. Curricula which increase student perceptions of potential achievement in an area (expectancy) and incorporate real-world experiences (value) have the potential to increase student attitudes toward a subject area (Fulmer, et al., 2019).

Social Constructivist Theory

Social constructivist theory was identified by Lev Vygotsky in 1978 and builds upon constructivism’s approach that learning is developed by leveraging student’s foundation of prior knowledge (Amineh & Asl, 2015). A key difference is that social constructivist theory highlights the social nature of building understanding around the concept(s) under study. The theory states that knowledge acquisition occurs through a two step process: first through social interactions with peers and secondly by individual internal processing for future use (Amineh & Asl, 2015; Walker & Shore, 2015). Inquiry-based curricula, such as mySci and OpenSciEd, rely on the social interactions among peers to collectively understand science concepts (OpenSciEd, 2019; Washington University in St. Louis Institute for School Partnership, 2020).

Expectancy-Value Theory

Expectancy-Value theory was developed by John William Atkinson in the 1950s and 1960s as a way to try to understand both achievement and motivation of individuals (Eccles, 1983). In the 1980s Jacquelynne Eccles and Alan Wigfield applied the theory to educational settings to examine student academic achievement and attitudes (Wigfield & Eccles, 2000). When applied to education, expectancy-value theory examines the factors that influence student attitude, motivation, and academic achievement in different subject areas (Ball, et al., 2017; Eccles, 1983; Wigfield & Eccles, 2000). Two major factors in play are: expectancies for success, or how a student perceives their potential success in an academic area, and task values, or what factors influence how a student determines which activities are worth doing (Eccles, 1983). By incorporating relevant topics of study into the curriculum design of both mySci and OpenSciEd, the curricula aim to increase the task value perception of the students while experiencing them (OpenSciEd, 2021; Washington University in St. Louis Institute for School Partnership, 2019). Embedded within OpenSciEd unit design, are multiple opportunities for students to feel a sense of success as they figure out incremental pieces of scientific concepts which help them later explain the anchoring phenomenon under study, thus increasing student expectancies for success (OpenSciEd, 2021).

Purpose

Focusing on exploring curricular options which ensure that all students engage in science learning experiences relevant to their own personal experiences may help identify the impacts curricula may have on students' academic achievement and attitudes toward science. 5E instructional models begin to provide a place for students to share their personal experiences to move the classroom's thinking forward. The storyline instructional design explicitly incorporates opportunities for students to share their personal experiences to move forward the classroom's understanding of science phenomena. By identifying which curricular option best supports students' incorporation of their personal experiences and perception of ownership of learning, we seek to make recommendations for the school's future science curriculum choices.

Perspectives of Authors

Nina Blanton

A curriculum was selected by the district so that there would be a standard curriculum used across the district, to help address transient students. There is much discussion about gradual release but the mySci curriculum does not lend itself to gradual release. The gradual release of responsibility model of instruction suggests that cognitive work should shift slowly and intentionally from teacher modeling, to joint responsibility between teachers and students, to independent practice and application by the learner (Pearson & Gallagher, 1983).

During my teaching career students oftentimes do not feel like they can relate to the science content. Even though the mySci 5urriculum uses real life scenarios students fail to make the connection in their own lives in their specific demographics. Lessons are usually cookie cutter lessons that do not lend itself to student connections. While researching the problem I found that students take more ownership of their learning experience when they can create an experience that is meaningful to themselves.

Nicole Vick

Having been in the classroom for more than 15 years and using traditional teaching methods, 5E instructional models, and storyline instructional design, student engagement and excitement was highest with storyline instructional design. The biggest piece of evidence was when a student in an alternative school, who previously stated that science was the most difficult subject for them, repeatedly stated that they felt like a scientist and the way they were learning about science really made them think deeper than they had in the past. This anecdotal evidence from my classroom and hearing the excitement from other teaching colleagues using storyline instructional design in their classrooms, with similar results, piqued the interest to study the differences in 5E instructional model and storyline instructional design on student achievement and attitudes toward science.

Research Questions and Hypotheses

Research Questions

1: To what extent is there a difference between achievement in science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by end of unit assessment scores?

2: To what extent is the difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by My Attitudes Toward Science (MATS) survey (Hillman et al., 2016)?

Hypotheses

Null Hypotheses

$H_0$1: There is no significant difference between the achievement in science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by the end of the unit assessment scores.

$H_0$2: There is no significant difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by scores on the My Attitudes Toward Science (MATS) survey (Hillman et al., 2016).

Directional Hypotheses

H_1: There is an increase between the achievement in science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by the end of the unit assessment scores.

H_2: There is an increase between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by scores on the My Attitudes Toward Science (MATS) survey (Hillman et al., 2016).

Significance

The two curricula, OpenSciEd and mySci were compared in terms of student academic achievement and attitudes toward science. There has been little to no research comparing these two types of curricula. The mySci curriculum is heavily built on students' prior knowledge which lends itself to lack of student engagement. We are curious if a different curriculum design will enhance student academic achievement and attitudes toward science. This data could potentially help school districts subscribe to different curricula that are better suited for gradual release, improved student academic achievement, and engagement.

Definitions of Terms

5E instructional model: a series of five learning phases: engagement, exploration, elaboration, explanation, and evaluation, used to guide students through developing an explanation of phenomenon or problem (Bybee, 2006).

Attitudes toward science: “the feelings, beliefs, and values held about an object that may be the endeavor of science, the impact of science and technology on society, or scientists” (Akcay, et al., 2010).

Gradual release: gradual release of the responsibility model of instruction suggests that cognitive work should shift slowly and intentionally from teacher modeling, to joint responsibility between teachers and students, to independent practice and application by the learner (Pearson & Gallagher, 1983).

Learning progressions: movement towards an increasingly sophisticated understanding of a discipline-specific core idea (Stevens et al., 2013).

mySci curriculum: hands-on, inquiry-based curriculum which uses the 5E instructional model developed by the Institute for School Partnership at Washington University (2020).

OpenSciEd curriculum: phenomena-based, student-led instructional model which uses storyline instructional design developed by OpenSciEd (2022a).

Storyline instructional design: coherent sequence of lessons, in which each step is driven by students' questions that arise from their interactions with phenomena.

Limitations and Delimitations

Limitations

Due to students being randomly assigned the teacher for their eighth-grade science class, a potential limitation may arise in that the way students are split into classes could result in there not being a representative population of the school as a whole. In addition, a potential limitation was that cultural bias may be inherent in the mySci curriculum compared to the intentional design of OpenSciEd to avoid cultural bias (OpenSciEd, 2019). Since the mySci curriculum is currently used by the school district, we are unable to choose a comparable second curriculum designed to avoid cultural bias.

A limitation that greatly impacted the research was the return of the assent and consent forms. The population size was significantly reduced due the limited number of consent and assent forms that were returned by students.

A final limitation is the implementation process surrounding new curricula. Due to teacher shortage, the researcher, Nina Blanton, was the only teacher that implemented the OpenSciEd curriculum. Nina Blanton had not previously taught science using the OpenSciEd curriculum. An OpenSciEd curriculum training was held July 25, 2022. There was a limited timeline to complete the dissertation, therefore the researcher did not have prior practice in implementation of the OpenSciEd curriculum. Usually, it takes a full year for a teacher to be comfortably acclimated to a new curriculum.

Delimitations

While trying to measure and identify student attitudes toward science, possible delimitations lie in our choice to use quantitative data. Choice of content to compare may have also been a delimitation. The mySci Module 11 Space and OpenSciEd Unit 8.4 Earth in Space were the units chosen to compare. This choice was made due to the timeframe in which the mySci module was being taught in the district pacing guide. The two morning classes were chosen to be the mySci population because of the heavy population of students with Individualized Education Program (IEP). This allowed for the use of materials which had already been revised to align with IEP accommodations.

Summary

The impact of student attitudes toward science and the motivation to learn science is heavily influenced by curricula choices made by school districts. We expect our research data to support that a student-centered curriculum which allows for student buy-in and ownership of their educational journey as provided by the OpenSciEd curriculum increases both student achievement and attitudes toward science. This ownership allows for increased student confidence in the sciences. Having this confidence at the middle school level will improve students' attitude and motivation toward science during high school and beyond. Due to increased confidence, we should also see a direct correlation to academic achievement.

Chapter 2

Literature Review

A quasi-experimental design was used to compare two curricula's, mySci and OpenSciEd, impact on student achievement and student attitudes toward learning science among middle school students. Chapter two provides an overview of two theoretical frameworks which underpin both curricula instructional models, Expectancy-Value and Social Constructivist Theory. Both theoretical frameworks, when applied to instructional models, have the potential to impact students' attitudes toward science and student achievement (Anderson, 2002; Aktamis, et al., 2016; Minner, et al., 2010; Wigfield & Eccles, 2000; Teppo, et al., 2021).

Search Description

The literature search strategy made use of keywords to identify research that could be applied. Keywords included, but were not limited to, 5E instructional design, storyline curriculum design, expectancy-value theory, social constructivist theory, student academic achievement, and student attitude towards science. EBSCO Academic Complete and ERIC search engines were used resulting in a total of 1099 articles, dissertations, books, and reports. Of those, 87 were reviewed and sorted into several themes: Expectancy-Value Theory (5), Social Constructivist Theory (11), 5E instructional model (23), storyline instructional design (21), attitudes toward science (9), academic achievement and teaching methodology (12), and coherence perspective (6).

Theoretical Frameworks

The effectiveness of two curricula on students' academic achievement and attitudes toward science around patterns related to space phenomena in four eighth grade classrooms in an urban setting was evaluated. Two theoretical frameworks define the scope of our research. Eccles' adaptation of Expectancy-Value Theory is used to frame the understandings around student attitudes toward science. A common thread connecting both 5E instructional model and storyline instructional design is the importance of group learning, which embodies Vygotsky's Social Constructivist Theory.

Expectancy-Value Theory

The psychological and developmental components of Expectancy-Value Theory (EVT) help frame the definitions of expectancy and value. In EVT, expectancy is defined as the student's belief about his or her ability to perform well on a given task (Wigfield & Eccles, 2000). In order to understand the expectancy a student has on a future task, we must also consider how students view their abilities. Wigfield & Eccles (2000) identify that student's beliefs of ability are rooted in the present levels of success whereas expectancies are rooted in future expectations of success.

In EVT, value is defined to have four components: "attainment value or importance, intrinsic value, utility value or usefulness of the task, and cost" (Wigfield & Eccles, 2000, p. 72). The attainment value refers to the importance of achievement while intrinsic value refers to enjoyment (Wigfield & Eccles, 2000). Utility value is defined as the usefulness of the task to the student's future (Wigfield & Eccles, 2000). Students may consider science courses useful for extrinsic reasons such as admittance to college (Wigfield & Eccles, 2000). Cost refers to the emotional, physical, or financial commitment required by the task (Wigfield & Eccles, 2000). A science course may cost students time due to studying or a financial payment in the form of tuition.

The combined task value has shown to strongly predict students' intentions to take future courses. The most immediate precursors of such performance variables as task choice and persistence are individuals' expectancies or subjective probabilities of success and the value they place on successful attainment (Eccles, 1983). The student's choice to participate in science, persistence in science, and performance can be explained by the expectancy-value model of achievement and performance (Wigfield & Eccles, 2000).

Social Constructivist Theory

Vygotsky's Social Constructivist Theory identifies the relationship between learning and social interactions which aid in learning. When considering the social aspects of learning, language and its use is central. Language is key to student development of concepts when educators implement Social Constructivist Theory in their classrooms (Shepardson & Britsch, 2015). The term language is meant to imply any form of communication, verbal, written, drawn, and physical gestures which help students explain and make sense of phenomena (Shepardson & Britsch, 2015). Social interactions using language allows for social cognitive growth followed by a period of internalization which occurs within the individual (Amineh & Asl, 2015; Cakir, 2008; Leach & Scott, 2003).

Within the science classroom, Social Constructivist Theory approaches shift the classroom from teacher-centered to student-centered (Teppo, et al., 2021). Teachers act as facilitators and guides in student learning along students' Zone of Proximal Development (ZPD) through teacher-student and teacher-group interactions (Amineh & Asl, 2015; Cakir, 2008). A students' ZPD is the, "distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Cakir, 2008, p. 194). Through the use of formative assessments, teachers can identify a student's ZPD and appropriately place them into collaborative groups to increase their development (Eastwell, 2002).

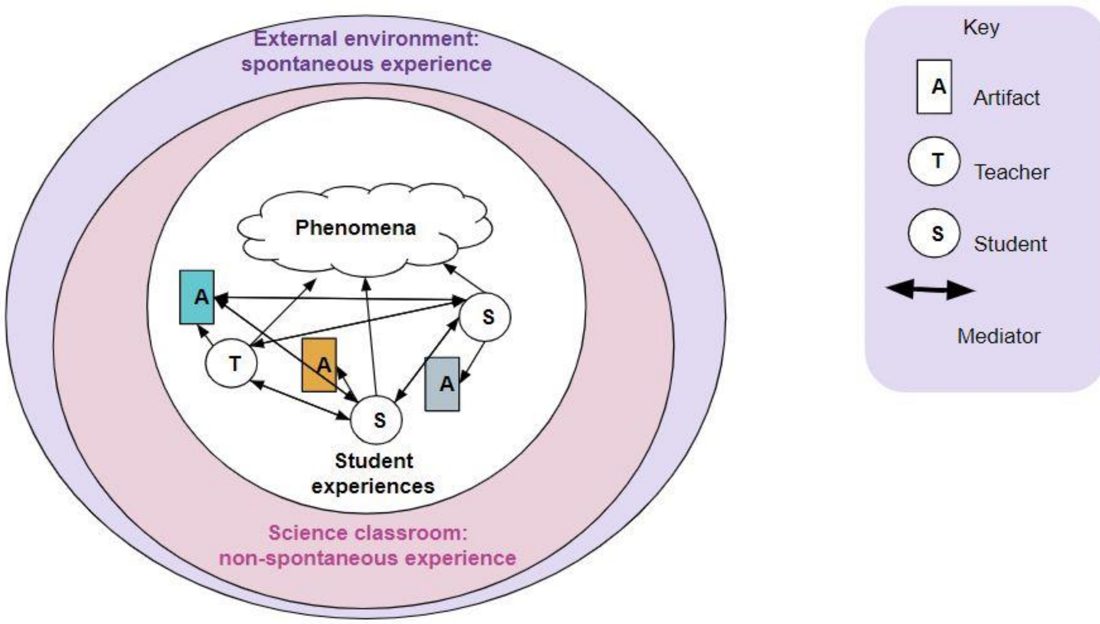
The student-centered classroom positions students as active participants in their learning. Students work together to construct knowledge in a way in which they relate their experiences, or spontaneous concepts, to the scientific understandings, or non-spontaneous concepts, being presented within the classroom (Cakir, 2008; Leach & Scott, 2003; Shepardson & Britsch, 2015). Through a unit of study using Social Constructivist Theory, students should come to see their, "spontaneous concepts as part of a system of relationships," related to the non-spontaneous concepts they learned in the classroom (Cakir, 2008, p. 195). Eastwell (2002) identifies the teacher's role in a student-centered classroom should act to:

- Connect classroom learning (non-spontaneous) with every day (spontaneous) concepts;
- Elicit student ideas;
- Implement activities that build on students' current and prior knowledge;
- Facilitate discussions to come to shared understandings;
- Plan for teacher-student and student-student interactions;
- Provide opportunities for more open-ended investigations.

For students to be successful in the student-centered classroom, they also must build and use various tools to allow for sense making around the phenomena under study (Shepardson & Britsch, 2015). Tools for success fall under two main categories: technical and psychological. Technical tools are those that allow students to expand the way they experience a phenomenon (Shepardson & Britsch, 2015). This could include the use of digital scales, microscopes, and force sensors. Psychological tools are the ways in which we make sense of information gathered with technical tools (Shepardson & Britsch, 2015). These could be artifacts, such as models, drawings, and graphs, or the way we talk about science by providing relevant evidence to support an explanation. Shepardson and Britsch (2015) identify the social world of what is happening within the science classroom and student experiences during learning in Figure 2.1.

Figure 2.1

The Social World of the Science Classroom



Note: Adapted from “Mediating Meaning in the Social World of Science Classroom”, by D.P. Shepardson and S. Britsch, 2015, *Electronic Journal of Science Education*, *19*(4).

The teacher acts as a mediator between students, artifacts, and phenomena. Teachers could be the ones which first share the phenomena with students, as well as ask students about phenomena they have experienced. Students can also act as mediators between artifacts and other students. One such teaching strategy which leverages students as mediators to other students is the use of jigsaw groups (Amineh & Asl, 2015).

Various studies have pointed to both increased student academic achievement and attitudes toward science in student-centered classrooms (Anderson, 2002; Aktamis, et al., 2016; Minner, et al., 2010; Teppo, et al., 2021), while others say there are potential negative impacts (Cairns & Areepattamannil, 2017; Jiang & McComas, 2015). The positioning of the students as the drivers of their learning in the storyline instructional model may indicate that students have increased academic achievement and more positive attitudes toward science.

Review of Literature

5E Instructional Model

The 5E instructional model was developed over “25 years ago” and was adapted from the “learning cycle described by J. Myron Atkin and Robert Karplus” (Bybee, 2014, p. 10). Incorporating “cognitive psychology, constructivist-learning theory, and best practices in science teaching,” the 5E instructional model aims to increase student engagement and achievement in science by giving students opportunities to study phenomena or solve problems over longer periods of time compared to teacher-centered (lecture-style) classrooms (Duran & Duran, 2010, p. 51). In the 5E instructional model, students learn science content through five phases, engage, explore, explain, elaborate, and evaluate. This is a shift from teacher-centered classrooms and incorporates more student-centered, active learning in an effort to use scientific principles to solve problems and explain phenomena. A key difference in the 5E instructional model is the use of conceptual coherence in the unit design process (Lipsitz et al., 2017). When thinking of teacher-centered instruction, one can imagine it as a series of chapters in a book, with one not necessarily connecting content from one chapter to the next, or structural coherence (Lipsitz et al., 2017). “Conceptual coherence describes the conceptual flow and sequencing of science ideas within a single learning model lesson that helps students understand a disciplinary core idea and a scientific phenomenon (Ramsey, 1993)” (Lipsitz et al., 2017, p. 76). While Lipsitz et al. describes the idea of conceptual coherence within a lesson, the 5E instructional model should be conceptually coherent during the entire unit (Bybee, 2014).

Another difference when comparing the 5E instructional model to teacher-centered classrooms is the role of the teacher. While the teacher has a large role in the engagement phase of the 5E instructional model similar to a traditional lecture-style role, the remaining phases of the 5E instructional model, the teacher's role can vary. In some phases, the teacher is more of a guide to help students in developing their understanding of scientific concepts and principles (Bybee, 2014; Duran & Duran, 2010; Fazelin et al., 2010); while in other phases, the teacher steps in and does pointed, direct instruction (Bybee, 2014; Duran & Duran, 2010).

5E Instructional Model and Social Constructivist Theory

The 5E instructional model is influenced by Social Constructivist Theory as it seeks to make learning student-centered and uses the idea of social interactions to move forward students' conceptual understandings of scientific concepts and principles. A summary of each and the role of the teacher and students is described in Table 2.1 (Ansberry & Morgan, 2007, p. 32; Bybee, 2009, pp. 5-9). Parallels to Eastwell's (2002) identifiers for the teacher's role in classrooms implementing Social Constructivist Theory have been underlined. Also aligned to Social Constructivist Theory are the varied level of interactions between teacher-student and student-student. During a 5E instructional model unit, students are developing scientific understanding through small group social interactions during both the explore and elaboration stages (Ansberry & Morgan, 2007; Bybee, 2009). Large-group interactions and teacher-student interactions can take place during all stages of the 5E instructional model (Ansberry & Morgan, 2007).

Table 2.1

Teacher and Student Roles in 5E Instructional Model Learning Phases

Learning Phase	Role of Teacher	Role of Students
Engage	Generate interest and curiosity, raise questions, and assess current knowledge.	Focus on the object, situation, or task presented by the teacher.
Explore	Provide time for students to work together, observe and listen during student-student interactions, and ask probing questions to redirect students during investigations.	Explore knowledge and skills to establish relationships, observe patterns, and identify variables.
Explain	Ask students to provide evidence or clarify their responses, leverage students' previous experiences when providing explanations, encourage students to explain in their own words and then provide scientific vocabulary.	Listens to the teacher as they build explanations.
Elaborate	Have students apply scientific concepts, skills, and vocabulary to new situations and remind and refer students to consider alternative explanations.	Engage in discussion and determine what new information is needed.
Evaluate	Observe and assess student application of new concepts and skills, allow students to have time to reflect and self-evaluate their learning, and ask open-ended questions.	Use acquired skills, evaluate understanding, and communicate solutions.

Note: Adapted from "More Picture-perfect Science Lessons: Using Children's Books to Guide Inquiry, Grades K-4," by Ansberry, K. and Morgan, E., 2007, *NSTA Press*, p. 32. Adapted from "The BSCS 5E Instructional Model and 21st Century Skills: A Commissioned Paper Prepared for a Workshop on Exploring the Intersection of Science Education and the Development of 21st Century Skills," by Bybee, R., 2009, *The National Academies Board on Science Education*, p. 5-9.

In Carrejo and Reinhartz's 2014 study, the 5E instructional model with a focus on student modeling was used to build eighth grade students' understanding around the concepts of forces and motion. Students developed models during all 5 phases in a variety of different situations, individual, partner, small group, and whole group. The use of modeling was chosen as it enables students to move from more concrete understandings to abstract understandings (Carrejo & Reinhartz, 2014). Teachers embedded opportunities for students to compare and evaluate peer models, as well as revise their own models based on interactions with peers. Using Shepardson and Britsch's (2015) social world of the science classroom model (figure 2.1), the teacher and other peers acted as the mediators between other students and models (artifacts). The models incorporated a variety of experiences, including videos, hands-on investigations, readings, and additional data sets (Carrejo & Reinhartz, 2014). Because of the social nature of interactions and role of the teacher as a mediator between artifacts, the forces and motion unit exemplifies the relationship between 5E instructional model and Social Constructivist Theory (Carrejo & Reinhartz, 2014).

Student Academic Achievement

The 5E instructional model effects on student academic achievement has been studied at length. These studies focused on differences in student academic achievement comparing traditional science instruction and 5E instruction (Acisli, et al., 2011; Cakir, 2017). Acisli, et al. (2011) examined students in a first-year university general physics course where half of the test subjects experienced traditionally taught lessons and the other experienced 5E lessons over the course of seven weeks. Pre- and post-tests were administered and they determined no significant differences between the two groups' pre-test scores (Acisli, et al., 2011). Upon completion of instruction, the post-test was administered and a t-test was used to evaluate differences in mean post-test scores (Acisli, et al., 2011). A significant difference was found where students experiencing 5E instruction scored higher than their peers (Acisli, et al., 2011). A meta-analysis of 32 studies and theses comparing traditional and 5E instruction showed significant differences in student academic achievement with students positively benefiting from 5E instruction (Cakir, 2017). Overall, the studies conducted point to students having positive academic gains as a result of experiencing science learning using the 5E instructional model compared to traditional science instruction.

Student Attitudes Toward Science

Inquiry based learning curricula, such as the 5E instructional model, have been shown to positively impact student attitudes toward science. A meta-analysis of 21 articles and theses found that there was a significant positive effect on student attitudes toward science as a result of experiencing the 5E instructional model compared to traditional science instruction (Cakir, 2017). A study on implementation of 5E instruction compared to textbook instruction with Taiwanese junior high students found statistically significant differences in the attitudes of students pre- and post-instruction (Lin, et al., 2014). Students experiencing 5E instruction had a higher mean score measuring science attitudes than those experiencing textbook instruction (Lin, et al., 2014).

While the majority of studies show a positive effect of the 5E instructional model on student attitudes, one study indicated a negative effect (Cramer, 2012). Cramer (2012) suspects that the negative effect could be due to, “unfamiliarity of the process itself negatively impacted students’ comfort level” (p. 24). The author’s explanation for the discrepancy from the literature is entirely plausible. Overwhelmingly, the 5E instructional model has shown a positive correlation in student attitudes toward science.

OpenSciEd Storyline Instructional Design

OpenSciEd is a partnership of 10 states, a consortium of curriculum developers, science education leaders, and experts working to create robust, open-source instructional materials designed to reach K-12 learners (McNeill & Reiser, 2018). The OpenSciEd storyline instructional model uses NGSS as the framework for development

(Edelson, et al., 2021). OpenSciEd design specifications call for all units to be driven by the use of an anchoring phenomena or design challenge (Edelson & Mohan, 2018). The anchoring phenomenon routine calls on students to engage with a puzzling phenomenon, attempt to make sense using their prior knowledge, and to develop questions for future study (Edelson & Mohan, 2018). Throughout the remainder of the unit, students experience a series of lessons which incorporate additional phenomena in an effort to explain the anchoring phenomena (Edelson & Mohan, 2018). The instructional model calls on teachers to, “create a context for learning, choreograph learning experience, and facilitate productive social interactions” (Edelson, et al., 2021, p. 782).

OpenSciEd Storyline Instructional Design and Social Constructivist Theory

Like the 5E instructional model, the OpenSciEd storyline instructional design makes use of Social Constructivist Theory and student-centered classrooms to make sense of and explain phenomena. The OpenSciEd storyline instructional design puts discussion and students working in a variety of group settings, individual, partner, small group, and whole group at the forefront (Edelson & Mohan, 2018). Design specifications also point out that units should engage students in the, “incremental revision and synthesis of ideas,” as well as have students use various representations (artifacts) both at the individual and class levels (Edelson & Mohan, 2018, pp. 8-9). Each OpenSciEd instructional unit uses four teaching routines: anchoring phenomena, navigation, putting the pieces together, and problematizing (Reiser, et al., 2021). A summary of each and the role of the teacher and students is described in Table 2.2 (Reiser, et al., 2021, pp. 811-823). Parallels to Eastwell’s (2002) identifiers of the teacher’s role in classrooms implementing Social Constructivist Theory have been underlined.

Table 2.2

Teacher and Student Roles in OpenSciEd Storyline Instructional Design Teaching Routines

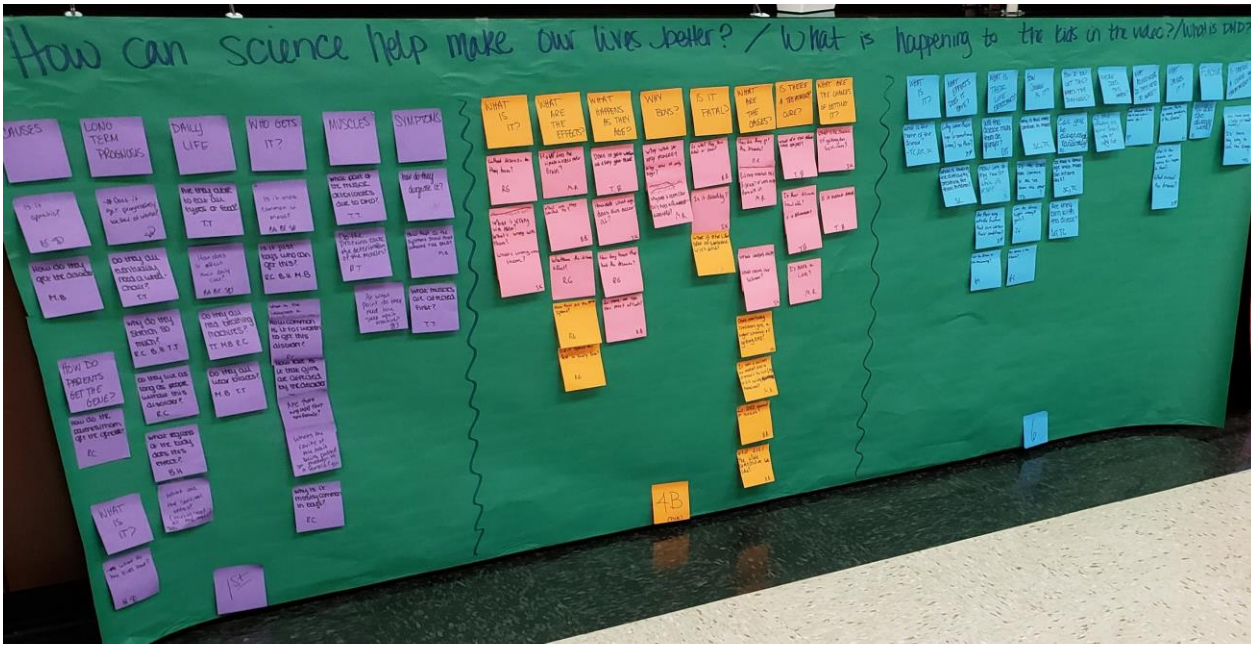
Teaching Routine	Role of Teacher	Role of Students
Anchoring Phenomena	Anchor students' science work in questions their class has developed, recorded on the Driving Question Board.	Explore, attempt to make sense of, ask questions around, and identify initial investigations to explain the anchoring phenomena.
Navigation	Position students as partners in figuring out how to make progress on their questions.	Reflect on the progress made towards answering class questions and determine where to go next.
Putting the Pieces Together	Partner with students in the process to develop explanations, models, and solutions.	Work individually and collaboratively to develop explanations, models, and solutions.
Problematizing	Work collaboratively with students to identify unanswered questions and identify explanatory gaps to direct further work.	Identify areas of disagreement in models when applied to a new situation.

Note: Adapted from "Storyline Units: An Instructional Model to Support Coherence from the Students' Perspective," by B.J. Reiser, M. Novak, T.A.W. McGill, and W.R. Penuel, 2021, *Journal of Science Teacher Education*, *32*(7), p. 805-829 (https://doi.org/10.1080/1046560X.2021.1884784)

A key shift in the OpenSciEd storyline instructional design is giving epistemic agency to students. Epistemic agency can be defined as "students being positioned with, perceiving, and acting on, opportunities to shape the knowledge building work in their classroom community” (Miller et al., 2018, p. 6). This is illustrated in Table 2.2 where student-developed questions, collected on the Driving Question Board, guide the navigation of the unit from lesson to lesson. Figure 2.2 shows an example Driving Question Board generated by high school students in their biology course. Students were introduced to an anchoring phenomenon, a brief video of children affected with Duchenne’s Muscular Dystrophy (DMD). Students then shared their observations and questions about the children in the video. Prior to development of the Driving Question Board, students shared their experiences, researched DMD, developed initial models to explain what is happening to someone with DMD, and compared their models as a way to generate more questions (inquiryHub RPP, 2018). Throughout the unit, students refer back to the Driving Question Board. Epistemic agency by using the Driving Question Board as part of the navigation routine is built into the unit at key points. Student epistemic agency is also seen in both the putting the pieces together and problematizing routines.

Figure 2.2

Example Student-Generated Driving Question Board



Note: Three different class sections of questions are shown in the image (purple, orange and pink, and blue). The top sticky note for each column represents the agreed-upon topic for that set of questions.

All OpenSciEd storyline units are field tested prior to public release to ensure that the design shifts epistemic agency to students. During the field test, both teachers and students respond to surveys to check that the units are following the instructional model called for in the *OpenSciEd Design Specifications* (Edelson & Mohan, 2018) and students are figuring out the intended scientific understandings (Edelson, et al., 2021). Table 2.2 shows teacher feedback regarding how often students are guiding the direction of the unit by: asking questions, reflecting on learning, and synthesizing new understandings with current understandings (Edelson, et al., 2021, p. 793).

Table 2.3

Teacher's reports of frequency of activities by students across six units

Activity	Mean	Standard deviation
Students discussed connections between the focus of the day's lesson and the anchoring phenomenon.	2.279	0.878
Students discussed what we figured out in a previous lesson at the beginning of class.	2.882	0.82
Students updated the Driving Question Board.	1.391	0.861
Students discussed what they figured out at the end of the lessons.	2.797	0.861
Students discussed the knowledge they made that helped them make progress on questions from the Driving Question Board.	1.725	0.938

Note. Teachers selected one of the following for each unit: 0 = In no lessons, 1 = In a few lessons, 2 = In half the lessons, 3 = In most lessons, 4 = In nearly every lesson. Adapted from "Developing Research-Based Instructional Materials to Support Large-Scale Transformation of Science Teaching and Learning: The Approach of the OpenSciEd Middle School Program," by Edelson, D.C., Reiser, B.J., McNeill, K.J., Mohan, A.M., Novak, M., Mohan, L., Affolter, R., McGill, T.A.W., Bracey, Z.E.B., Noll, J.D., Kowalski, S.M., Novak, D., Lo, A.S., Landel, C., Krumm, A., Penuel, W.R., Van Horne, K., Gonzalez-Howard, M., and Suarez, E., 2021, *Journal of Science Teacher Education*, *32*(7), 780-804. (https://doi.org/10.1080/1046560X.2021.1877457)

Student discussions are occurring in at least half of lessons to reflect on learning and connect to prior learning. In terms of student questions, they are engaged with developing and answering questions a few times throughout the duration of the unit. This typically occurs during the putting the pieces together and problematizing routines

(Reiser, et al., 2021). Social Constructivist Theory is exemplified by the OpenSciEd storyline instructional design through shifting epistemic agency from teachers to students (Eastwell, 2002; Reiser, et al., 2021; Teppo, et al., 2021). A recent paper presentation sharing data from ten educators during their experience teaching with storylines supports this claim as themes around student epistemic agency and ownership in learning were seen both in journal entries and whole group discussion of students' engagement during storyline enactment in the classroom (Ko, et al., 2023).

Student Academic Achievement

Studies have shown that students are more likely to enroll in advanced mathematics courses when they are confident of their performance (Spence, 1983). The assumption can be made that this is also true for other STEM courses such as science. Because of the curricular design of storyline, building epistemic agency, students feel more confident in STEM related areas. Student's increased confidence could be attributed to the shift of the classroom as a community where students are allowed to take risks and challenge each other as they make progress towards explaining phenomena (Reiser, et al., 2021). Another key shift towards building student confidence, and thus future enrollment in science coursework, revolves around the idea that there are no right answers, rather we revise our current explanations based on new evidence. By positioning students as the drivers of information and concept development in the classroom, storyline curriculum builds student confidence and possible likelihood of students enrolling in future science coursework.

Student Attitudes Toward Science

The OpenSciEd Storyline instructional design allows student choice in the development of questions which support the direction of lessons (Edelson & Mohan, 2018). Middle school students thrive on choices built into the curriculum (Gentry, et al., 2000). When teachers provide choices, they are allowing students to tailor their education to their strengths and interests (Gentry et al., 2000). Ultimately, this leads to increased student motivation to learn and produce better quality projects (Gentry et al., 2000). The storyline instructional design developed by the OpenSciEd Consortium lends itself to this type of curriculum (Edelson & Mohan, 2018). This type of educational ownership by the student leads to greater perceived ability to succeed which could possibly promote higher student motivation. Curriculum is only part of students' attitudes toward science; there are also social implications. Personal attitudes and interests of the students as individuals will impact students' views of science (Bybee & McCrae, 2011). By leveraging student interest and ownership of their learning, storyline curriculum should positively impact student attitudes toward science.

Summary

While research has been done on the effectiveness of both curricula on student achievement and attitudes toward science, no research has been done comparing the 5E instructional model and OpenSciEd storyline instructional design. Research conducted on the effectiveness of storyline instructional design is relatively new because storyline instruction was developed within the past 13 years and has recently been used to address the Next Generation Science Standards (NGSS), introduced in 2013 (NGSS Lead States, 2013). The 5E instructional model has been used for nearly 40 years and has considerably more research done evaluating the effectiveness of the instructional model on student achievement and attitudes toward science. The current research exhibits a gap in comparing the two curricula which use active learning guided by principles of both EVT and Social Constructivist Theory.

Chapter 3

Methodology

Chapter three outlines and explains the methods that were used to test the hypotheses and answer the research questions. The methodology focuses on investigating the effects of a NGSS storyline instructional design curriculum, OpenSciEd, on eighth grade student achievement in science and student attitudes toward science compared to the current 5E instructional design-based curriculum, mySci. The overall objective was to identify and explore instructional strategies that might increase the engagement of students in science and better prepare them for success in future science courses. Discussion of the planned research design, research questions, sample, instrumentation, and methods of data collection and analysis are discussed in the following paragraphs.

Research Questions and Hypotheses

Research Questions

1: To what extent is there a difference between achievement in science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by end of unit assessment scores?

2: To what extent is the difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by My Attitudes Toward Science (MATS) survey (Hillman et al., 2016)?

Hypotheses

Null Hypotheses

$H_0 1$: There is no significant difference between the achievement in science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by the end of the unit assessment scores.

$H_0$2: There is no significant difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by scores on the My Attitudes Toward Science (MATS) survey (Hillman et al., 2016).

Directional Hypotheses

H_1: There is a significant difference between the achievement in science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by the end of the unit assessment scores.

H_2: There is a significant difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by scores on the My Attitudes Toward Science (MATS) survey (Hillman et al., 2016).

Research Design

A quantitative research approach was used to analyze data collected near the beginning of the first semester of two integrated science sections using the mySci curriculum and two integrated science sections using the OpenSciEd curriculum in order to measure the effects of curriculum choices on middle school student achievement and motivation to learn science. Quantitative research involves following a post-positivist worldview by which phenomena are observed and measured by collecting numerical data (Creswell, 2014; Grix, 2010). Creswell (2014) explains that quantitative research often focuses on identifying variables and examining the relationships among them. Quantitative researchers identify an independent variable, which may be a treatment or intervention that can be administered to a sample, and then quantify the association or effect it has with or on other variables known as dependent variables. The influence of additional variables must be strictly addressed by a research design that controls these additional influences and specifically explains the impact of other factors that may moderate results (Creswell, 2014).

A quasi-experimental design was used to compare data from students experiencing two different teaching strategies. A quasi-experimental design was chosen because the participants in each group could not be randomly assigned. When participants are not randomly assigned to the two different teaching strategies, it is possible that the two groups could be dissimilar. Therefore, a non-equivalent, pretest and posttest control-group design was used to differentiate the effects of each teaching strategy on the two student groups (Creswell, 2014).

Two measures of quantitative data were collected. Students took a pre/posttest measuring academic achievement around a single NGSS performance expectation (PE). Scores on the pre- and post-test were used to compare the achievement of students experiencing the OpenSciEd curriculum to students experiencing the mySci curriculum. Along with the academic pre- and post-test, the My Attitudes Toward Science (MATS) survey was administered. MATS scores were used to compare motivation to learn science of students experiencing the OpenSciEd curriculum to students experiencing mySci curriculum. One group experienced the OpenSciEd unit 8.4: *How are we connected to the patterns we see in the sky and space?* The second group used the school’s established curriculum, mySci module 11: *How can we as space scientists analyze data to plan a space mission?*

Determination of Instructional Units

Determining the OpenSciEd unit and mySci 5E module for comparison was dependent on several factors, including, district pacing, similarities between the NGSS performance expectations (PEs) covered between the two units, and length of units. The units for comparison were chosen by examining when they are taught during the school year. Using the mySci 5E module sequence of the school district, potential parallel OpenSciEd units to choose were those aligned to mySci 5E modules taught earlier in the school year. The degree of alignment to the NGSS standards was considered. Because one of the research questions targets differences in academic achievement, the decision was made to choose units with parallel, or as close to parallel content as possible, considering NGSS performance expectation (PE) alignment. The final factor for choosing the units for comparison was instructional time. Implementation of OpenSciEd units typically takes longer as both teachers and students adjust to the differences in instruction. The final consideration was to choose an OpenSciEd unit that had a recommended days of instruction that was less than the mySci 5E module, so the days of instruction of the unit were comparable.

District Sequencing of Units

The first consideration in choosing comparison units of study was based on the pacing guide of the school district. The mySci modules taught toward the beginning of the 2022-2023 school year were preferred to those being taught later in the school year because of the timing needed to collect data. That consideration narrowed down perspective mySci modules to the first three taught in the school year: module 11 space; module 4 noncontact forces; and, module 3, force and motion. All three mySci modules were examined for their NGSS standards alignment and then compared with available OpenSciEd units. Three OpenSciEd units were considered due to possible connections around phenomena: unit 8.4 Earth in space; unit 8.3 forces at a distance; and unit 8.1 contact forces. Each set of NGSS PEs were determined for the respective units and compared, see Table 3.1.

Table 3.1

NGSS Performance Expectation (PE) Alignment of mySci and OpenSciEd Instructional Units

Unit	mySci Module 11	OpenSciEd Unit 8.4	mySci Module 4	OpenSciEd Unit 8.3	mySci Module 3	OpenSciEd Unit 8.1
PEs	MS-ESS1-1	MS-ESS1-1	MS-PS2-3	MS-PS2-2	MS-PS2-1	MS-PS1-2
	MS-ESS1-2	MS-ESS1-2	MS-PS2-5	MS-PS2-3	MS-PS2-2	MS-PS2-2
	MS-ESS1-3	MS-ESS1-3	MS-PS3-2	MS-PS2-5	MS-PS3-1	MS-PS3-1
		MS-PS2-4		MS-PS3-1	MS-PS3-2	
		MS-PS4-2		MS-PS3-2	MS-PS3-5	
				MS-PS3-5		

Note: Engineering Design (ETS) PEs were not included as part of the PE inventory for comparison. Performance expectation lists for selected units from: OpenSciEd, n.d; Washington University in St. Louis Institute for Partnership, 2019.

Due to the strongest PE alignment between mySci module 11 and OpenSciEd unit 8.4, the decision was made to investigate and compare those two units. Students in one group will experience mySci module 11 and students in another group will experience OpenSciEd unit 8.4, at the start of the 2022-2023 school year.

NGSS Standards Alignment

The two units chosen for study are both concerned with Earth's place in space, scale, and use an Earth-based perspective to explain patterns people experience (OpenSciEd, 2021; Washington University in St. Louis Institute for Partnership, 2019). OpenSciEd and mySci claims on which NGSS standards are addressed within each respective unit were evaluated using the EQuIP Rubric for Science (EQuIP, 2021). As part of the development process, OpenSciEd submitted the unit to the NextGen Science

Peer Review Panel (NextGen Science, n.d.). Because the mySci unit being used as part of the study had not been submitted to the NextGen Science Peer Review Panel (PRP), an independent EQuIP review was conducted by former PRP member, Kristin Rademaker (personal communication, February 20, 2022). Appendix A shows the alignment comparison between the two units as found on unit overview information or EQuIP reviews (K. Rademaker, personal communication, February 20, 2022; NextGen Science, 2021; OpenSciEd, 2021; Washington University in St. Louis Institute for Partnership, 2019).

NGSS Performance Expectations and Disciplinary Core Ideas

Comparison of the NGSS performance expectations (PEs) shows that the two units are aligned where both cover three of the same Earth and Space Science (ESS) PEs (see Appendix A). The OpenSciEd unit includes two additional Physical Science (PS) PEs, not covered by the mySci unit. Guidance provided by OpenSciEd includes information on how to adjust the unit by skipping the portion addressing the PS PEs (OpenSciEd, 2021). Similar differences arise in the alignment of Disciplinary Core Ideas (DCIs). Both align in terms of the ESS DCIs addressed in the unit, but the OpenSciEd unit also incorporates PS DCIs not covered in the mySci unit. By adjusting the sequence of lessons in the OpenSciEd unit, the PEs and DCIs will match those covered by the mySci unit. Evaluation of the claimed DCIs using the EQuIP rubric found inadequate evidence for the mySci unit and extensive evidence for the OpenSciEd unit (K. Rademaker, personal communication, February 20, 2022; NextGen Science, 2021). The review of the mySci unit with the EQuIP rubric did not identify enough pieces of evidence in the materials to demonstrate that students are engaging and learning about any of the three dimensions of NGSS claimed by the developers. Due to the lack of evidence identified by the reviewer, students may not be learning DCI content knowledge as they are taught the mySci unit compared to students being taught with the OpenSciEd unit. This has the potential to affect student academic achievement posttest scores.

NGSS Science and Engineering Practices

Comparison of the NGSS Science and Engineering Practices (SEP) shows more significant differences than those of the PEs and DCIs. Science and Engineering Practices are how students are engaging with the DCIs to make sense of phenomena. The mySci unit claims one additional SEP, Using Mathematics and Computational thinking (see Appendix A). Whereas the OpenSciEd unit claims two additional SEPs, Analyzing and Interpreting Data and Obtaining, Evaluating, and Communicating Information. Both units identify Developing and Using Models. Because of these differences, considerations of which SEPs to include in the assessment were adhered to as to not give one group, mySci or OpenSciEd, an advantage over the other. The EQuIP rubric review of the mySci unit found inadequate evidence of the use of identified focal SEPs to help students make sense of phenomena (K. Rademaker, personal communication, February 20, 2022). In contrast, the EQuIP rubric review of the OpenSciEd unit found extensive evidence of the use of identified focal SEPs (NextGen Science, 2021). Again, discrepancies in the mySci unit's claimed SEP elements and evidence for them in the EQuIP review, may have implications in student academic performance on the posttest.

NGSS Crosscutting Concepts

Comparison of the NGSS Crosscutting Concepts (CCCs) from the two strategies focus on Patterns and Scale, Proportion, and Quantity (see Appendix A). The OpenSciEd unit claims one additional CCC, Systems and System Models. In the development of the assessment, items developed by the OpenSciEd unit with explicit use of Systems and System Models were removed or altered in a way to not penalize students being taught with the mySci unit. The EQuIP review of the mySci unit found inadequate evidence of the use of either of the focal CCCs (K. Rademaker, personal communication, February 20, 2022). Rather, students are instructed to, “look for patterns in a graph,” or, “compare sizes and distances of different objects” (K. Rademaker, personal communication, February 20, 2022). While both focal CCCs are implied, students are not actively using them as a lens to figure out DCI understandings (K. Rademaker, personal communication, February 20, 2022). The EQuIP review of the OpenSciEd unit found adequate evidence of students using CCCs to build understanding of DCIs (NextGen Science, 2021). Feedback around the rating pointed to students not developing CCCs throughout the unit (NextGen Science, 2021). Again, discrepancies in the mySci unit’s claimed CCC elements and evidence for them in the EQuIP review, may have implications in student academic performance on the posttest, although possibly not at the level of as DCIs or SEPs.

Comparison of Instructional Practices

The final evaluation of the two curricula to ensure equity amongst the experiences of students in the mySci and OpenSciEd groups centered around assessment types, days of instruction, and teaching methodologies. Table 3.2 summarizes the similarities and differences between the two curricula as found in their respective overview documents.

Table 3.2

Comparison of Instructional Practices and Time between mySci and OpenSciEd Space

mySci module: *How can we as space scientists analyze data to plan a space mission?*	OpenSciEd unit, 8.4: *How are we connected to the patterns we see in the sky and space?*
Instructional Design	
5E	Storyline
Portions Taught	
Concept 1; Sessions 1-9 Concept 2; Sessions 1-4 Concept 3; Sessions 1-6 Concept 4; Sessions 1-7	Lesson set 1; Lessons 1-5 Lesson set 2; Lessons 6-7 Lesson set 4; Lessons 13-17
Instructional Days	
28	24
Groupings	
Whole class, small group, partner, individual	Whole class, small group, partner, individual
Activity Types	
Investigations, reading, video/image, simulation, direct instruction	Investigations, reading, video/image, simulation, discussion

Note: Instructional design characteristics for selected units from: OpenSciEd, 2021; Washington University in St. Louis Institute for Partnership, 2019.

The school district's mySci sequencing document outlines which portions of module 11 are taught in classes, as the module in its entirety is not used. OpenSciEd provides guidance on how to adjust the lessons taught in class to students to remove portions of the unit to address differences in school district scope and sequences (OpenSciEd, 2021). Researchers used this information to remove those lessons which address the

PS PEs not covered in the mySci module. To determine days of instruction, the total number of instructional minutes outlined in those sessions or lessons were totaled and then divided by students' time in class (67 minutes). With the reduction in lessons of the OpenSciEd unit, and also considering that first-time implementation typically takes longer, the length of instructional days is comparable to the mySci module. Finally, teaching methodologies were examined. Both curricula incorporate various levels of classroom groupings, including individual reflection time. The activities students engage with the curricula are similar, except for one key difference in that the mySci module calls for direct instruction whereas OpenSciEd relies heavily on discussion (OpenSciEd, 2021; Washington University in St. Louis Institute for Partnership, 2019). After all of the comparative analysis of the two curricula, a conclusion can be made that they are comparable and students in the OpenSciEd group would not experience any educational losses.

Population and Sample

Population

The population of interest included 44 eighth grade students enrolled in science courses at a large, suburban, Midwestern, public middle school during the 2022-23 academic school year. The overall demographics of the middle school in 2021 included a total enrollment of approximately 707 students consisting of 2.8% White, 89.8% African American, 0% Asian, 3.4% Hispanic, and 4.0% other or multiple races (Missouri Department of Elementary and Secondary Education, n.d.). In 2021, 100% of the school population received free or reduced lunch (Missouri Department of Elementary and Secondary Education, n.d.). This school was selected because one of the researchers is employed at this school. Classes were selected based on sections taught by the researcher.

Sample

The middle school offered 12 sections of eighth grade integrated science during the 2022-2023 school year, four of which were taught by the researcher. A convenience sample of 18 students enrolled in two sections of eighth grade integrated science were selected for the OpenSciEd group. A convenience sample of 26 students enrolled in two sections of eighth grade integrated science were selected for the mySci group.

An attempt was made to attain a sample large enough to minimize the effects of mortality and sampling error. A random sample could not be obtained because middle school students' courses are selected by their counselor. As students enroll in school the counselors are charged with building their schedules. The only guideline taken into consideration when scheduling is if a student has an IEP (Individualized Educational Program) or not.

Professional Development for Implementation of OpenSciEd Unit

The OpenSciEd middle school science program is an open educational resource (OER), meaning that it is freely available (OpenSciEd, 2022a). While this allows all access for all school districts nationwide, implementation with fidelity is hard to achieve without professional development around the instructional materials. OpenSciEd offers teacher professional learning (PL) programs, which can be costly, as well as freely available PL materials (OpenSciEd, 2022b). The teacher was trained using the freely available PL materials by a certified OpenSciEd PL provider on July 25, 2022. Unit-specific PL was used to build teacher's familiarity with the unit prior to implementation. The teacher participated in an immersion experience, where they played the role of a student experiencing the first lesson of the unit. Specific attention was paid to leading discussions and navigation routines, both within and between lessons, to help increase the level of fidelity of implementation as both of these areas can be particularly difficult for teachers transitioning away from other teaching methods to NGSS storylines. Follow up PL opportunities were provided as needed during the implementation process.

Instrumentation

Instrumentation Design

In order to fairly assess student academic achievement and attitudes toward science, instrumentation was carefully designed and selected. The mySci module has a developer-created pre- and post-test which is administered before students start the unit and after completion. OpenSciEd contains an assessment overview of the unit which details where formative and summative assessment opportunities are found throughout the unit. Since the mySci module does not include PEs around light and its properties, the related OpenSciEd assessments were not included as part of the combined pre- and post-test. Because the research design was to measure quantitative data, all qualitative student responses on the two instruments used were transformed into quantitative measurements. For the academic tool, a numerical rubric was used to score qualitative student responses. For the attitudes toward science tool, responses were transformed to a Likert scale measurement.

Design Goals

The goals of quantitative data were: (a) to determine if experiencing the OpenSciEd unit (independent variable) has an effect on achievement in science (dependent variable); (b) to determine if experience the OpenSciEd unit (independent variable) has an effect on student attitudes toward science (dependent variable). Two measures of quantitative data were collected. One set of measures was collected before students started the unit of study and again once students completed the unit of study.

Academic Achievement Measurement Tool Development

An assessment tool to measure students' academic achievement of one PE was developed using the pre- and post-test from mySci module 11 and lesson four and six assessment opportunities from OpenSciEd unit 8.4. The pre- and post-test academic assessment was designed to be completed in a single class period of 67 minutes. One PE was chosen, MS-ESS1-1: Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons, as both curricula contain assessments which directly address both on developer-created assessments. Items which aligned with the targeted PE were used to build the pre- and post-test and can be found in Appendix B. The final pre- and post-test were analyzed for reading level to ensure it is academically appropriate. The school's special education teacher developed a modified version of the pre- and post-test to administer to students with IEPs (C. Saulter, personal communication, September 6, 2022).

Instrument Validation. Validation of the composite pre- and post-test was done through an external review. The composite pre- and post-test and each developer's assessments were sent to an individual trained in NGSS assessment alignment to ensure the PE targeted by the assessment was addressed and to determine there was no bias towards one developer's assessment and the others. The external review determined that the combined assessment addressed the identified PE and did not show bias toward one developer or the other (K. Rademaker, personal communication, July 23, 2022). Upon comparison of the modified version to the original version of the pre- and post-test, several items were not considered for data analysis as the level of modification resulted in the items no longer adequately assessing the targeted PE (Appendix C).

Student Attitudes Toward Science Measurement Tool

Hillman et al. (2016) My Attitudes Toward Science (MATS) survey was used to compare student attitudes toward science before and after experiencing the two units. The instrument has 40 items that measure four dimensions: (1) Attitude towards the subject of science; (2) Desire to become a scientist; (3) Value of science to society; and (4) Perception of scientists (Appendix D). The MATS, as a multidimensional instrument, can measure several facets of students' attitudes toward science and can be scored easily. One of the criteria used in the design of the MATS was that it should be able to be used with children from the elementary- to the high-school level (ages 8–18 years). The literature search indicated that four dimensions could be assessed at all grade levels. Attitude towards science dimension consists of fourteen items, seven positivity worded and seven negatively worded items (Hillman, et al., 2016). The desire to become a scientist dimension is composed of two items, one positivity worded item and one negatively worded item (Hillman, et al., 2016). The perception of a scientist or stereotypical attitudes toward who is a scientist dimension consists of twelve statements reflecting stereotypes in science (Hillman, et al., 2016). Lastly, the value of science to society dimension consists of twelve items, six positively worded items and six negatively worded items (Hillman, et al., 2016). The MATS survey uses a Likert-like scale consisting of: disagreed a lot, disagreed a little, had not decided, agreed a little, or agreed a lot. Permission to use the MATS survey in its entirety was requested in an email to the principal author, Dr. S.J. Hillman on July 29, 2021. Researchers received correspondence from Dr. S. I. Zeeman, secondary author, giving permission to use the MATS survey (personal communication, July 29, 2021). A copy of the email correspondence was included with IRB documentation.

Instrument Validation. Validity tests were performed on the initial 46 items in the instrument. Face validity is an assessment of how survey items appear to measure a particular idea as perceived by the general public or a person taking the survey (Hillman et al., 2016). Wording was carefully selected and evaluated to be at the third-grade reading level this helped to ensure that children taking this instrument could, on its face, understand the questions. Each question involved statements that clearly reflected a science attitude.

Content validity involves assessment by persons who are experts in the content of the particular area. Content validity was addressed in this project by having potential items for all dimensions randomly assigned a number, organized by numerical order, and assessed by the 32 teachers and graduate science students (Hillman et al., 2016).

Using Cronbach's alpha coefficient, the MATS scores were internally consistent for three of the four dimensions for most grades (Hillman et al., 2016). Cronbach's alpha coefficients reflect how closely related items within a scale are or, in the case of MATS, within a dimension.

Data Collection

Curriculum implementation and data collection ran from September 12, 2022 through November 17, 2022. Students completed the MATS and academic pre-test from August 29th through September 30, 2022. Upon completion of the two units, students took the post-MATS survey from November 17 through December 1, 2022 and the academic post-test on November 11-12, 2022.

Data Analysis

The data analysis involved examining the relationship between the independent variable: science curriculum, and two dependent variables: science academic achievement and attitude toward science. Student pretest scores on the composite assessment were compared to posttest scores after experiencing either mySci module 11 or OpenSciEd unit 8.4. Student scores on the MATS survey before and after instruction were used as the measure of student attitudes toward science. An overall scale score and four subscale scores measuring student attitudes toward science, desire to become a scientist, perception of scientists, and value of science to society were calculated and analyzed from the MATS survey results.

The student pretest scores were used as the baseline measure of science academic achievement. These scores were compared to student scores on a posttest after they completed the curricula module or unit. Independent t-tests and two-tailed t-tests comparing the mean pretest scores and section scores of the OpenSciEd and mySci groups were conducted to determine if their baseline scores are significantly different.

Independent student t-tests were used to analyze statistical differences in MATS overall mean scores and subscale scores of attitudes toward science, desire to become a scientist, perception of scientists, and value of science to society which represents the dependent variable student attitude toward science for the independent variable (group) (Cody, 2021). A two-tailed t-test was used to analyze if the means of the overall and subscale scores for the OpenSciEd and mySci groups were statistically different from the scores of the whole student population participating in the study. Multiple student t-tests are chosen because they can reveal if the independent variable (group) is associated with statistically significant differences in the means of multiple dependent variables (student attitude toward science as measured by overall and sub scores on MATS survey). Table 3.3 contains a timeline of data collection and data analysis.

Table 3.3

Timeline of Data Collection and Statistical Analysis

Start date	Action	End date
August 29, 2022	Students take academic pretest and MATS survey.	September 30, 2022
September 13, 2022	Students are taught either mySci or OpenSciEd units.	November 11, 2022
November 11, 2022	Students take academic posttest and MATS survey.	December 1, 2022
January 16, 2023	Scoring academic posttest for internal consistency.	April 15, 2023
April 15, 2023	Academic pre- and posttest statistical analysis.	May 4, 2023
January 19, 2023	MATS pre- and post-unit statistical analysis.	February 6, 2023

Ethical Considerations

Ethical considerations around the use of minors in research were at the forefront of the research. The population centered on eighth grade students, persons typically between 13-15 years of age. Researchers submitted the research design proposal to the University of Missouri St. Louis Internal Review Board on January 27, 2022 through their eCompliance platform. Approval of the project was received on May 12, 2022. Students were informed by the researcher teacher that their participation in the research was voluntary. Those who chose to participate were provided with student assent (Appendix E) and parental consent forms (Appendix F). To protect student identities but still allow for comparison of each student's academic pre- and post-test scores and MATS survey, each student was assigned a specific, random identifier. Students were assigned a random Id number using a formula on Google. The formula is as follows: function x = RANDBETWEEN (1,000,99999). The key of these identifiers will be stored for five years on a password protected computer. Physical pre- and post-test academic assessment data was collected and will be stored in a secured location for five years. The MATS survey was administered electronically using Google Forms. Access to, and storage of, the Google Form responses was limited to the researchers. Google Form responses will be stored for five years.

Threats to Validity

Threats to validity are ever present. Even if background information, pretest, and/or supplemental information was collected there could potentially be a threat to validity. If there are no true measurements of difference between the mySci and OpenSciEd groups, those differences could potentially be the real cause for the outcome of the study.

Internal Threats

Sound research design minimizes internal threats to validity that challenge whether the outcomes of experiments were related to the intervention or other factors (Creswell, 2014). Internal threats of maturation, selection, and attrition involve the sound research design that minimizes internal threats to validity that challenge whether the outcomes of experiments were related to the intervention or other factors (Creswell, 2014). Internal threats of maturation, selection, and mortality involve the participants (Creswell, 2014).

Maturation. All participants are in eighth grade which minimizes the effect of maturation as all participants will be of similar age and assumed to mature similarly throughout the academic year as they experience a science curriculum.

Selection. A convenience sample of 18 students enrolled in two sections of eighth grade integrated science were selected for the OpenSciEd group after they turned in student assent and parental consent forms. A convenience sample of 26 students enrolled in two sections of eighth grade integrated science were selected for the mySci group after they turned in student assent and parental consent forms. The total sample size was 44 students.

Attrition. Attrition was also addressed with a large sample size that may minimize the effect of students who may withdraw during the study. Diffusion of treatment, resentful demoralization, and compensatory rivalry are additional threats to the internal validity of experimental designs that have OpenSciEd and mySci groups (Creswell, 2014). These threats occur when participants of one group communicate with another group and influence the outcomes of experiments (Creswell, 2014). Internal threats related to the experimental treatment were minimized by selecting participants near the beginning of the academic school year and limiting the research to one content module, thereby restricting the amount of time participants had to communicate with members of the other group. In addition, participants were not informed that science curricula are being compared. Furthermore, until after data are collected and analyzed, there was no indication that either curriculum was beneficial or harmful, therefore the mySci group would not have reason to resent or consider the OpenSciEd group to be a rival. Instrumentation can also be an internal threat to validity if the instrument changes between the pretest and posttest (Creswell, 2014). The instrumentation threat to internal validity was addressed by showing (in the instrumentation sub-section) that these tests demonstrate convergent validity and high correlation.

External Threats

Creswell (2014) explained “external validity threats arise when experimenters draw incorrect inferences from the sample data to other persons, settings, and situations” (p. 176). The main threats to external validity involve the selection of participants and setting. The setting is a large middle school in a large suburban district in Missouri. The mySci and OpenSciEd curricula at the research site were taught by a veteran teacher having more than ten years of experience teaching science. In order to minimize threats to external validity, generalizations about the results were not made beyond the specific population studied.

Summary

A quantitative, quasi-experimental research design was used to investigate the effects of OpenSciEd curriculum compared to the currently used mySci curriculum. Analysis of data collected from 44 students experiencing either curriculum (NGSS storylines) was used to determine the effects of one curriculum on achievement in science and student attitude toward science compared to the other. A convenience sample of two sections of students enrolled in eighth grade integrated science was selected for the OpenSciEd group (n=18) and two sections of students enrolled in eighth grade integrated science will be selected for the mySci group (n=26). All participants were eighth grade students attending a large, predominantly African American, suburban, Midwestern, public middle school. A researcher-developed composite assessment based on the assessments of the curriculum developers was used to measure achievement in science. Independent, two-tailed t-tests were used to analyze the results of the mySci and OpenSciEd groups on achievement in science. The MATS survey was used to measure student attitudes toward science within the four dimensions, attitude toward science, desire to become a scientist, perception of scientists, and value of science to society (Hillman et al., 2016). Independent, two-tailed t-tests were used to analyze the results of mySci and OpenSciEd groups on the MATS dimensions of attitude, desire, perception, and value.

Chapter 4

Data Analysis

Chapter four shares the statistical data that was used to inform the evaluation hypotheses and research questions discussed in chapter 5. The data analysis focused on statistically analyzing the data collected to evaluate the effects of a storyline instructional design curriculum, OpenSciEd, on eighth grade student achievement in science and student attitudes toward science compared to mySci curriculum which uses the 5E instructional model. The overall objective was to identify and explore instructional strategies that might increase the engagement of students in science and better prepare them for success in future science courses. Discussion of the research questions, methods of data analysis, and discussion of data follows.

Research Questions and Hypotheses

The following discussion shares the results of the research examining the effects of two inquiry-based curricula on student academic achievement and attitudes toward science. Two research questions were developed that framed the results. The first research question is concerned with academic achievement. The second research question is concerned with student attitudes toward science.

Research Questions

1: To what extent is there a difference between achievement in science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by end of unit assessment scores?

2: To what extent is the difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by My Attitudes Toward Science (MATS) survey (Hillman et al., 2016)?

Hypotheses

Statistical analysis of the quantitative results addresses the null hypotheses developed for each of the research questions by comparing the dependent variable values of the OpenSciEd and mySci groups. OpenSciEd groups are those students who received instruction using the OpenSciEd curriculum. mySci groups are those students who received instruction using the mySci curriculum.

Null Hypotheses

$H_0$1: There is no significant difference between the achievement in science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by the end of the unit assessment scores.

$H_0$2: There is no significant difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by scores on the My Attitudes Toward Science (MATS) survey (Hillman et al., 2016).

Directional Hypotheses

H_1: There is a significant difference between the achievement in science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by the end of the unit assessment scores.

H_2: There is a significant difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by scores on the My Attitudes Toward Science (MATS) survey (Hillman et al., 2016).

Data Description

Data were collected from a sample of 44 eighth grade students enrolled in science at a large, urban, Midwestern, public middle school. The OpenSciEd group consisted of 18 students. The mySci group consisted of 26 students. Both groups of students were enrolled in eighth grade science, but received instruction using two different inquiry-based curricula. Scores on a developer created assessment were used to measure student academic achievement. Scores on the My Attitudes Toward Science (MATS) survey were used to measure student attitude toward science (Hillman et al., 2016). All data were entered into Google Sheets and then saved as a Microsoft Excel document and checked for errors. The data were then imported into Statistical Analysis Software (SAS) for descriptive and inferential statistical analysis.

Data Analysis

Student Academic Achievement

In the first phase of data analysis, students completed the end of unit assessment as a pre-test to determine if there were significant differences in their academic achievement before experiencing either curriculum. The end of unit assessment consisted of six items and a total of 15 points possible (see Appendices B and C). Items 8, 10, 11, and 12 are developed by mySci. Three of those, items 8, 11, and 12, are multiple choice questions. Item 10 is a free response question. Images 1 and 2 are developed by OpenSciEd and are free response questions. Table 4.1 shows the point value breakdown for each item on the assessment.

Table 4.1

Academic Assessment Score Values

	Item 8	Item 10	Item 11	Item 12	Image 1	Image 2
Point Value	1	6	1	1	3	3

A scoring rubric was used to determine the student scores on the assessment. The rubric was adopted from the two curricula that were used to create the unit assessment. Student pre-tests were scored separately by researchers and then those scores were compared to norm the rubric scoring process. Independent t-tests were completed for the overall differences between pre-test and post-test scores. A two-tailed t-test was completed to check that there were no significant differences between the mySci and OpenSciEd groups. In the second stage of analysis, students completed the same end of unit assessment that was used as a pre-test for a post-test. Scores were normalized between two graders and statistical analysis was completed. Table 4.2 shows the independent t-test analysis of the differences in pre- and post-test scores. Figure 4.1 shows the comparison of pre- and post-test score means. Table 4.3 shows the normality test of the mySci and OpenSciEd group.

Table 4.2

t-test Results: Comparison of Differences between Pre-Test Scores and Post-Test Scores of OpenSciEd and mySci Groups

Group	*Pre-test score M*	*Post-test score M*	*Difference M*	SD Difference
OpenSciEd (n=18)	1.58	3.11	1.53	1.24
mySci (n=26)	1.98	3.04	1.06	2.13

Note: Mean difference between average pre- and post-test scores.

Figure 4.1

Academic Pre- and Post-test Scores for OpenSciEd and mySci Groups

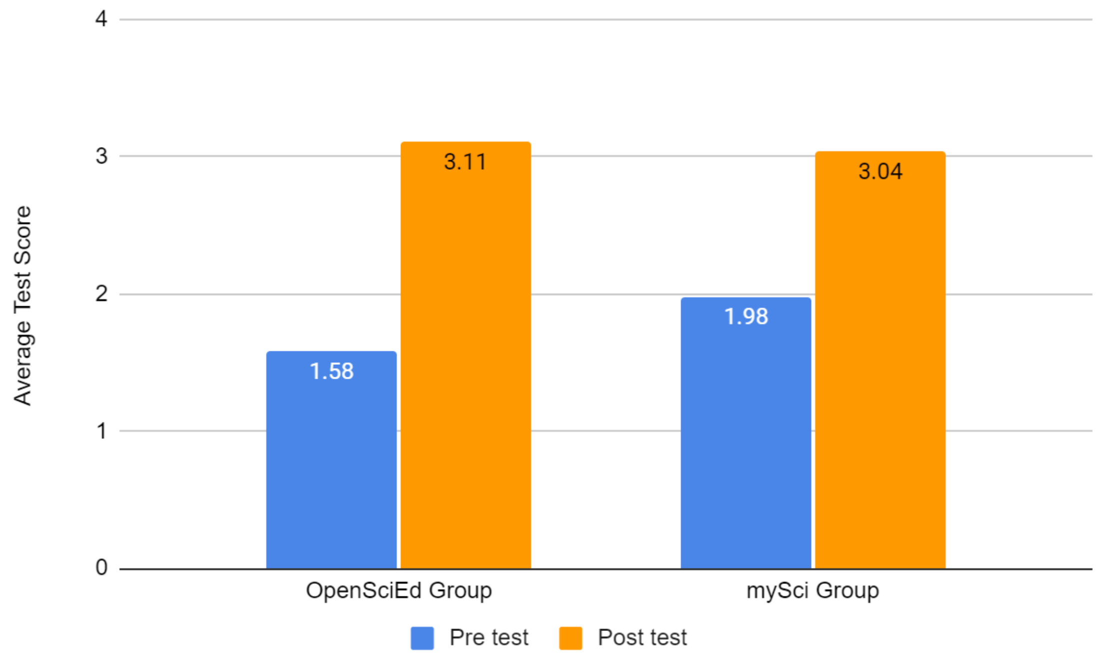


Table 4.3

Test for Normality Results: Comparison of Differences of OpenSciEd and mySci Groups

Group	Shapiro- Wilk Test for Normality		
	Statistic	p value	
OpenSciEd (n=18)	0.94	Pr<W	0.33
mySci (n=26)	0.95	Pr<W	0.29

My Attitudes Toward Science (MATS) Survey

In the first phase of data analysis, students completed the MATS survey prior to receiving instruction with either curriculum. The survey gave five statements to students to choose from which were converted into Likert scale values for the data analysis: Disagree a lot (5), Disagree a little (4), Have not decided (3), Agree a little (2), and Agree a lot (1). Item dimension identification can be found in Appendix E. Items that are negatively worded were reverse-scored before analysis per the scoring guidelines developed by Hillman et al. (2016). One student's score from the OpenSciEd group was removed as they did not complete the MATS survey both pre- and post-instruction. Table 4.4 shows the results of the mean MATS survey pre-instructional scores for the OpenSciEd and mySci groups. Table 4.5 shows the same data for post-instructional scores. Figure 4.2 shows the comparison of student's scores in the OpenSciEd group. Figure 4.3 shows the comparison of student's scores in the mySci group.

Table 4.4

MATS Mean Pre-Instructional Scores of OpenSciEd and mySci Groups

Group	Overall Mean		Attitude		Desire		Perception		Value	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
OpenSciEd (n=17)	2.80	0.46	2.80	0.99	4.29	0.81	3.02	0.52	2.35	0.77
mySci (n=26)	2.99	0.38	2.97	0.75	4.46	0.76	3.29	0.39	2.46	0.71

Note: M = mean and SD = standard deviation. Mean scores are based on Likert scale values.

Table 4.5

MATS Mean Post-Instructional Scores of OpenSciEd and mySci Groups

Group	Overall Mean		Attitude		Desire		Perception		Value	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
OpenSciEd (n=17)	2.93	0.43	2.90	0.85	3.76	1.00	3.36	0.53	2.39	0.73
mySci (n=26)	3.05	0.31	2.96	0.61	4.19	1.02	3.45	0.53	2.56	0.65

Note: M = mean and SD = standard deviation. Mean scores are based on Likert scale values.

Figure 4.2

MATS Pre- and Post-Instructional Mean Survey Scores for OpenSciEd Group

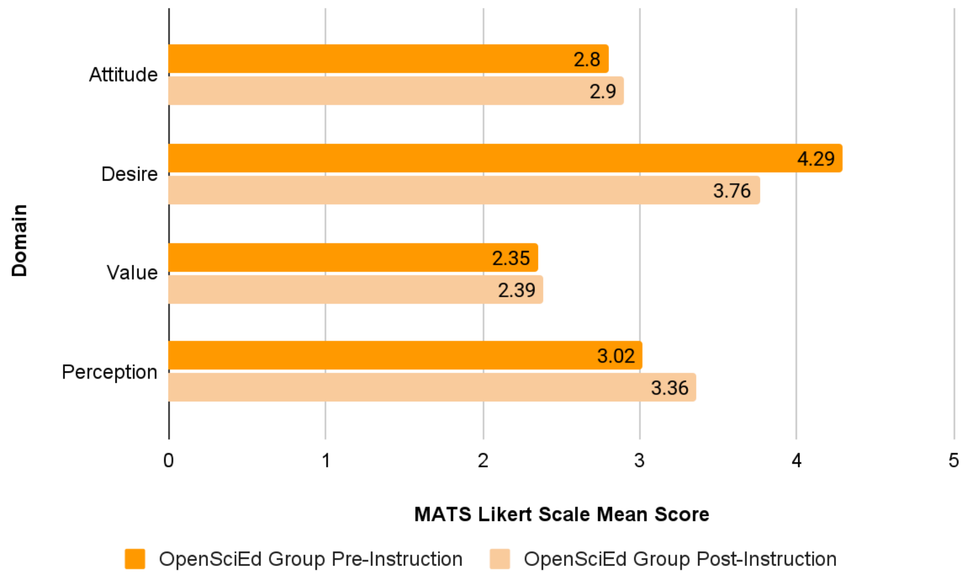
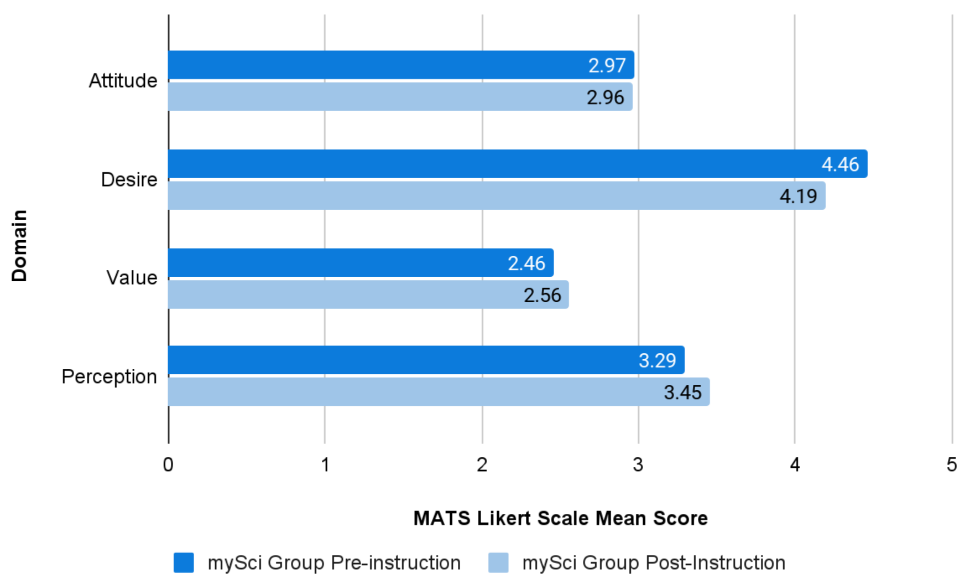


Figure 4.3

MATS Pre- and Post-Instructional Mean Survey Scores for mySci Group



The data were checked for normality using the Shapiro-Wilk test, which is used for small sample sizes. The pre- and post-instructional mean scores for desire to be a scientist did not represent a normal distribution (see Appendix G). The pre- and post-instructional mean scores for the overall score and all other domains did represent a normal distribution.

Two-tailed t-tests were performed to determine if there were statistical differences between either group and the whole population. Table 4.6 shows the t-test results of pre-instructional MATS scores. Table 4.7 shows the t-test results of the post-instructional MATS scores.

Table 4.6

t-test Results: Comparison MATS Pre-Instructional Survey Scores for OpenSciEd and mySci Groups

Scale	OpenSciEd (n=17)		mySci (n=26)			
	M	*SD*	*M*	*SD*	*t Value*	*df*
Overall	2.80	0.46	2.99	0.38	1.43	41
Attitude	2.80	0.99	2.97	0.75	0.66	41
Desire	4.29	0.81	4.46	0.76	0.53*	41
Perception	3.02	0.52	3.29	0.39	1.96	41
Value	2.35	0.77	2.46	0.71	0.48	41

** distribution was not normal, Kruskal-Wallis chi-square statistic reported*

Table 4.7

t-test Results: Comparison MATS Post-Instructional Survey Scores for OpenSciEd and mySci Groups

Scale	OpenSciEd (n=17)		mySci (n=26)			
	M	*SD*	*M*	*SD*	*t Value*	*df*
Overall	2.93	0.43	3.05	0.31	1.10	41
Attitude	2.90	0.85	2.96	0.61	0.31	41
Desire	3.76	1.00	4.19	1.02	0.98*	41
Perception	3.36	0.53	3.45	0.53	0.56	41
Value	2.39	0.73	2.56	0.65	0.80	41

** distribution was not normal, Kruskal-Wallis chi-square statistic reported*

Two-tailed t-tests were performed on the differences in mean MATS domain scores of the pre- and post-instructional surveys to determine if there were statistical differences in the OpenSciEd and mySci group mean MATS scores gains. The data were checked for normality using the Shapiro-Wilk test. The differences in mean gain scores for the overall MATS score and domain scores were all normally distributed. Table 4.8 shows the t-test results of the comparison of mean MATS survey score differences for the OpenSciEd and mySci groups.

Table 4.8

t-test Results: Comparison Mean MATS Survey Scores Differences for OpenSciEd and mySci Groups

	OpenSciEd (n=17)		mySci (n=26)			
Scale	*M*	*SD*	*M*	*SD*	*t Value*	*df*
Overall	0.12	0.47	0.06	0.34	-0.47	41
Attitude	0.10	0.79	-0.01	0.73	-0.44	41
Desire	-0.53	-1.18	-0.27	-0.80	0.65	41
Perception	0.34	0.13	0.16	-0.00012	-1.40	41
Value	0.04	-0.18	0.10	-0.11	0.39	41

Discussion

Student Academic Achievement Results

The following section presents the discussion of the results for the null hypothesis focusing on student academic achievement.

> $H_0$1: There is no significant difference between the achievement in science by eighth grade students experiencing the OpenSciEd storyline science curriculum compared to those experiencing mySci 5E curriculum as measured by the end of the unit assessment scores.

Academic Pre- and Post-Test Differences Summary

- Table 4.2 indicates that the mySci group increased by a mean of 1.06.
- Table 4.2 also indicates that the OpenSciEd group increased by 1.53, which is greater than the mySci group.
- Table 4.3 shows that the mySci group does not resemble a normal distribution.
- Table 4.3 shows that the OpenSciEd group is normally distributed.

- The p-value for the differences in the mean is 0.36. The differences in the means were not large enough to be statistically significant.

My Attitudes Toward Science (MATS) Survey Results

The following section presents the discussion of the results for the null hypothesis focusing on student attitudes toward science.

> $H_0$2: There is no significant difference between attitudes toward science by eighth grade students experiencing the OpenSciEd storyline science curriculum compared to those experiencing mySci 5E curriculum as measured by scores on the My Attitudes Toward Science (MATS) survey (Hillman et al., 2016).

MATS Pre-Instructional Scores Summary

- The overall score and dimensional MATS scores for the mySci group are higher than that of the OpenSciEd group.
- The higher attitude toward school science MATS score for the mySci group indicates that they have a more positive attitude toward school science than the OpenSciEd group.
- Both groups have a high score for desire to become a scientist. This indicates that they have a desire to work in an area of science.
- The higher perception of scientists MATS score for the mySci group indicates that they have a more stereotypical ideation of scientists than the OpenSciEd group.
- The higher value of science to society MATS score for the mySci group indicates that they value science more than the OpenSciEd group.
- The scores for desire did not represent a normal distribution. The overall score and all other domains did represent a normal distribution. The t-test value reported for desire was the Mann-Whitney test since the data were not normally distributed.

- None of the MATS scores between the OpenSciEd and mySci group were significantly different as indicated by the t-test values. A lower t-test value, or those close to zero, indicate that the data support acceptance of the null hypothesis, or not statistically significant.

MATS Post-instructional Scores Summary

- The overall score and dimensional MATS scores for the mySci group are higher than that of the OpenSciEd group.
- The higher attitude toward school science MATS score for the mySci group indicates that they have a more positive attitude toward school science than the OpenSciEd group.
- The higher desire to become a scientist MATS score for the mySci group indicates that they have a desire to work in an area of science than the OpenSciEd group.
- The higher perception of scientists MATS score for the mySci group indicates that they have a more stereotypical ideation of scientists than the OpenSciEd group.
- The higher value of science to society MATS score for the mySci group indicates that they value science more than the OpenSciEd group.
- The scores for desire did not represent a normal distribution. The overall score and all other domains did represent a normal distribution. The t-test value reported for desire was the Mann-Whitney test since the data were not normally distributed.
- None of the scores between the OpenSciEd and mySci group were significantly different as indicated by the t-test values. A lower t-test value, or those close to zero, indicate that the data support acceptance of the null hypothesis, or not statistically significant.

MATS Pre- and Post-instruction Score Differences Summary

- The overall mean score for the OpenSciEd group compared to the mySci group had a larger difference gain, as indicated by the negative t-test value.
- The difference in means for attitudes toward school science scores showed a larger gain by the OpenSciEd group compared to the mySci group, as indicated by the negative t-test value.
- Both the OpenSciEd and mySci group's post-instruction mean scores in the desire to become a scientist domain decreased. The OpenSciEd group decrease was greater than the mySci group, as indicated by the positive t-test value.
- Both the OpenSciEd and mySci group's post-instruction mean scores for perception of scientists increased. The gain in scores was greater for the OpenSciEd group compared to the mySci group as indicated by the negative t-test value. This means that both groups had more stereotypical perspectives of scientists than they held on the pre-instructional administration of the MATS survey.
- Both the OpenSciEd and mySci group's post-instruction mean scores for the value of science to society increased. The mySci group had a greater increase than the OpenSciEd group, as indicated by a positive t-test value.
- None of the scores between the OpenSciEd and mySci group were significantly different as indicated by the t-test values. A lower t-test value, or those close to zero, indicate that the data support acceptance of the null hypothesis, or not statistically significant.

Summary

Independent, two-tailed t-tests were conducted on the difference in academic pre- and post-test scores for the OpenSciEd and mySci groups. No significant measurement of the differences in student's scores on the academic pre- and post-test was identified. Independent, two-tailed t-tests were conducted on the pre-instructional and post-instructional mean MATS survey scores for each dimension as well as the differences in student's mean scores on the MATS survey. No significant measurement between the two groups was identified.

Chapter 5

Conclusion

Maintaining student engagement throughout students' K-12 educational career has been a struggle for educators (Vedder-Weiss & Fortus, 2012). Prior research around instructional strategies has been limited to comparing traditional, or lecture-based, instruction to inquiry-based instruction. Studies have shown that use of inquiry-based instructional methods compared to lecture-based instruction positively impacts student engagement in science (Anderson, 2002; Aktamis, et al., 2016; Gibson & Chase, 2002; Minner, et al., 2010; Wang, et al., 2015). The researchers found no studies that referenced a comparison of two different inquiry-based instructional methods. Development of research examining the effects of two different inquiry-based instructional methods was done in an effort to provide data to influence curricular decisions.

Two inquiry-based curricula were examined to determine the impact on students' academic achievement and attitudes toward science, mySci and OpenSciEd. The school district currently uses mySci curriculum which uses the 5E instructional model. During the course of the unit, students engage with the 5E's: engage, explore, explain, extend, and evaluate as they work to explain a phenomenon (Bybee, 2014). Introduction of OpenSciEd curriculum was explored. OpenSciEd uses the storyline instructional design. As students experience the unit of instruction, they engage in four teaching routines: anchoring phenomena, navigation, putting the pieces together, and problematizing (Reiser, et al., 2021). The difference between the two approaches is the perception of coherence. In 5E, the teacher perceives the coherence of the unit and is able to explain why students are engaging in an activity. In storylines, the student perceives the coherence of the unit and is able to explain why they are engaged in the activity at that moment (Reiser, et al., 2021). This also represents a shift in epistemological agency from the teacher to the student. The evidence presented in this chapter justifies further research into the comparison of the effectiveness of different inquiry-based instructional methods.

Summary of Findings

The following discussion shares the summary of findings about the research examining the effects of two inquiry-based curricula on student academic achievement and attitudes toward science. Two research questions were posed and frame the summary of findings discussion. Table 5.1 summarizes the findings for each research question.

Table 5.1

Summary of Findings

Question	Findings
In response to question 1: *To what extent is there a difference between achievement in science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by end of unit assessment scores?*	● Students who experienced the OpenSciEd curriculum had an overall larger gain than those who experienced mySci. ● There were fewer students in the OpenSciEd group than there were in the mySci group. This appears to have an impact on the data trends.
In response to question 2: *To what extent is the difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum and those experiencing mySci curriculum as measured by My Attitudes Toward Science (MATS) survey (Hillman et al., 2016)?*	● The difference in students' attitudes toward school science showed a gain for all students, with a larger gain in the students experiencing OpenSciEd. ● The difference in students' attitudes toward school science showed a gain for all students, with a larger gain in the students experiencing mySci. ● All students held more stereotypical perceptions of scientists after instruction, with a larger gain in the students experiencing OpenSciEd.

Conclusions

The following discussions describe conclusions of the findings related to each research question's null hypothesis. Statistical analysis did not indicate any differences between the treatment, OpenSciEd, and mySci, strategies. The discussion of conclusions is related to trends seen in the data. Three conclusions were made based on trends in the data discussed in the following sections.

1. Students who experienced the OpenSciEd curriculum had a higher mean academic score than those that experienced mySci curriculum.
2. Students who experienced the mySci unit had higher MATS survey scores than students who experienced OpenSciEd.
3. Students who experienced the OpenSciEd unit had higher differences in pre- and post-instructional MATS mean survey scores for overall score and attitude, desire, and perception domains than students who experienced the mySci unit.

Student Academic Achievement

There has been much research about the 5E curriculum and storyline curriculum independently but very little research comparing the two in terms of their impact on student academic achievement. Data does exist for the impact of the 5E instructional model on student academic achievement when compared to traditional, lecture-based instruction. One study and a meta-analysis revealed that there are significant positive differences in student's academic achievement when they are in science classrooms implementing the 5E instructional model (Acisli, et al., 2011; Cakir, 2017). Currently there are no published studies measuring the impact of OpenSciEd storyline instructional model on student academic achievement. Research has shown that a key shift in building student confidence around science does take place as they experience OpenSciEd (Reiser, et al., 2021). This has the potential to correlate to positive academic achievement when experiencing OpenSciEd.

Null Hypothesis: There is no significant difference between the achievement in science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by the end of the unit assessment scores.

Conclusion 1: Students who experienced the OpenSciEd curriculum had a higher mean academic score than those that experienced mySci curriculum.

There is some indication that students experiencing OpenSciEd curriculum had a higher mean than those experiencing mySci curriculum as shown in Figure 4.1.

Student Attitudes Toward Science

Much research on the influence of instructional methods on student attitudes toward science has been conducted. Many studies point to a positive relationship between student's attitudes toward science in inquiry-based instructional methods (Anderson, 2002; Aktamis, et al., 2016; Minner, et al., 2010), while some research points to a negative relationship (Cairns & Areepattamannil, 2017; Jiang & McComas, 2015), and others say it depends on the environment (Mostafa, et al., 2018). One environmental factor pointed out by Mostafa, et al. (2018) is discipline. Classrooms where discipline in the classroom is lacking, in other words, classrooms with many disruptions, struggle with implementation of inquiry-based curricula (Mostafa, et al., 2018). Those distractions may also decrease student's attitudes toward that class, thus possibly influencing their feelings around the content. The investigation did not record data around possible effects of the classroom environment on student attitudes toward science.

Null Hypothesis: There is no significant difference between attitudes toward science by eighth grade students experiencing the OpenSciEd curriculum compared to those experiencing mySci curriculum as measured by scores on the My Attitudes Toward Science (MATS) survey (Hillman et al., 2016).

Conclusion 2: Students who experienced the mySci unit had higher MATS survey scores than students who experienced OpenSciEd.

The pre- and post-instructional scores for students in the two sections experiencing mySci were higher than students in the two sections experiencing OpenSciEd (figures 4.2 and 4.3). Since we would not want to see high scores for all domains, the overall score values are not as meaningful as analysis of the four domains included on the MATS survey. The higher the score for attitudes toward school science, the more favorable students think about classroom science settings. Both mean scores are around three out of five which corresponds to “Have not decided” on the MATS survey. This could be interpreted as students having no opinion around their feelings, both positive or negative, toward the science classroom. The higher the score for desire to become a scientist, the more likely students may be in pursuing science outside of the classroom setting. Two items on the MATS survey, one positively worded and one negatively worded (Appendix D) examine this domain. The OpenSciEd group score decreased, more toward the “Have not decided” option. The mySci group decreased, but still was above four which corresponded to the “Agree a little” option on the survey. Perceptions of scientists is the domain where a lower score is desired. A higher score on the Likert scale indicates that students have more stereotypical views of scientists. In both groups, their views of scientists became more stereotypical on the post-instructional surveys. The pre- and post-instructional scores for value of science to society domain indicate that students “Disagree a little” about science’s role in society. It is unclear as to why the mySci group mean scores were higher than the OpenSciEd group mean scores.

Conclusion 3: Students who experienced the OpenSciEd unit had higher differences in pre- and post-instructional MATS mean survey scores for overall score and attitude, desire, and perception domains than students who experienced the mySci unit.

Statistical analysis of the data did not reveal any statistical significance in the differences of pre- and post-instructional MATS survey scores between the OpenSciEd and mySci groups. A trend in the data did emerge, the gains for most domains were greater for students in the OpenSciEd group (Table 5.2). Again, discussion will consider each domain more so than the overall mean score as we would not want all scores to increase. The attitudes toward school science MATS score remained relatively stable for the mySci group whereas there was some increase for the OpenSciEd group. Desire to become a scientist decreased for both groups, with the OpenSciEd group moving down a level on the Likert scale, from “Agree a little” to “Have not decided.” Students' perceptions of scientists increased for the OpenSciEd group more than the mySci group. The desire of any curriculum would be to decrease this score as a higher score indicates that students have a more stereotypical view of scientists. The higher gain in the OpenSciEd group is especially surprising as the OpenSciEd unit incorporates interviews with BIPOC and LGBTQIA+ individuals to launch the unit. Students in the OpenSciEd group had similar feelings around science’s value to society. The mySci group saw an increase, but not enough to change the Likert scale level.

Table 5.2

Differences in MATS Mean Scores of OpenSciEd and mySci Groups Pre- and Post-Instruction

	OpenSciEd (n=17)			mySci (n=26)		
Domain	Pre	Post	Difference	Pre	Post	Difference
Overall	2.80	2.93	0.13	2.99	3.05	0.06
Attitude	2.80	2.90	0.10	2.97	2.96	- 0.01
Desire	4.29	3.76	- 0.53	4.46	4.19	- 0.27
Perception	3.02	3.36	0.34	3.29	3.45	0.16
Value	2.35	2.39	0.04	2.46	2.56	0.10

Limitations of Findings

Due to lack of returns of assent and consent the population size was drastically reduced. This reduction of population size contributed to the lack of normal distribution found in our data. Having more participants may have shown a significant difference in the OpenSciEd and mySci group based on data trends. Academic assessment tests were modified to accommodate students with IEPs. They were modified in such a way that many questions had to be eliminated. The mySci group classes were before lunch and the OpenSciEd group classes were after lunch, so the time of day may have also had an impact on data results.

Reflections of Researchers

Nina Blanton

Most students responded to the multiple-choice questions which were from the mySci curriculum while many of the short answer questions from the OpenSciEd curriculum were left blank. Many questions were eliminated from the assessment because over modifications were made for students that IEP. Both researchers felt with the modifications, the questions no longer evaluated whether or not the students understood the content. In hindsight a pilot should have been implemented before the actual data collection to ensure teacher familiarity with OpenSciEd curriculum. One wondering if the OpenSciEd questions could be reconstructed for improved student response and ease of grading for the teacher.

Nicole Vick

Although no significant relationships were identified in the data, the research conducted provided some evidence which warrants further study. The data around student academic achievement suggests that there is some positive correlation between student’s understanding around the phenomena of lunar cycles when experiencing the OpenSciEd curriculum compared to mySci. Due to the changes on the modified test, only one DCI of those claimed by MS-ESS1-1 was able to be assessed. Students’ understanding of seasonal changes due to the tilt of the Earth was unable to be assessed. In the OpenSciEd unit, students build this through examination of conflicting data using small scale models of the Earth and Sun. In the mySci unit, it is unclear as to how students figure out the role of Earth’s tilted axis in determining seasonal patterns. It does appear as if students are told that the axis is tilted. Comparing student’s scores on this portion of the assessment may have allowed for some interesting discussion around building understanding through modeling and data analysis versus being told information. The data around student attitudes toward science is also interesting, because of some of the unexpected results. Students’ scores for perceptions of scientists increased for both the OpenSciEd and mySci group. This is surprising to me because the OpenSciEd unit incorporates scientific ideas from groups that had not traditionally been honored in the scientific community.

Conducting the investigation was not without its difficulties. Implementation of storyline curricula is hard! From my personal experience, the first time through a storyline is really about just figuring out how to use the materials and getting used to the pedagogical shifts, especially getting comfortable with leading discussions. While we did plan for training on how to implement the OpenSciEd unit, I think we would have benefitted from a pilot study where Nina taught the unit we used prior to us using it for data collection. This would have allowed her to have more experience with OpenSciEd and feel a bit more comfortable with implementation. Another unanticipated event was the level of modifications on the pre- and post-instruction assessment. The expert we had review the academic pre-/post-test is a former special education teacher. We did not have her consider, as part of her review, what types of modifications would be appropriate for specific items. This could have helped prevent us from having to remove all questions related to seasonal changes, which would have allowed for more data to compare students' academic achievement between the two curricula.

Implications of Practice

The trends shown in the data for academic achievement show that there may be positive effects of OpenSciEd curriculum on student academic achievement compared to mySci curriculum. There is not sufficient evidence to claim the students in the OpenSciEd group out-performed those in the mySci group. The mySci group had more variation in scores than the OpenSciEd group which may have influenced the statistical significance of the data. Additional study over several units may elicit data which can be used to develop claims about student academic achievement while experiencing storyline curriculum compared to 5E curriculum.

Trends shown in the data for MATS survey domain scores indicate that there may be a positive effect of OpenSciEd curriculum on student attitudes toward school science compared to the gains of students experiencing mySci curriculum. It is of note, that the students experiencing mySci curriculum had higher scores in all MATS survey domains than the students experiencing OpenSciEd curriculum. A potential negative trend of students decreasing desire to become a scientist and increasing stereotypical ideation of scientists in both groups warrants further study.

Recommendations for Future Research

No research has been done comparing two inquiry-based science curricula on student academic achievement or attitudes toward science. The trends indicated in the data should be researched further with a larger sample size and over multiple curriculum units. Revision of the academic pre- and post-test to support students with IEPs in a way that would allow for evaluation of their science understanding should be completed prior to further studies. This would allow for evaluation of the entire PE being tested. Incorporation of qualitative data in the form of student and small group interviews could provide insight into some of the interesting trends seen in the MATS survey domain data.

Other research questions that came out of the investigation but were beyond scope of the investigation questions.

1. Do students in other grades in middle school, grades six through eight, have similar results when comparing OpenSciEd and mySci curricula?
2. Do students in the high school setting have results when comparing OpenSciEd and mySci curricula?
3. What impact does teacher’s experience with implementation of OpenSciEd curriculum have on student engagement with the materials?

Summary

An effort by educators and the educational research community has been around increased student engagement, epistemology, and achievement in science. Many studies have been conducted into which instructional models lead to more student engagement, increased student epistemology, and higher achievement in science. The use of inquiry-based instructional models have been shown to have a higher impact than traditional, lecture-based instructional models.

Two inquiry-based curricula which differ in who perceives unit coherence were investigated and their impacts on student academic achievement and attitudes toward science were investigated. The OpenSciEd curriculum which uses the storyline instructional model was compared to mySci. The current curriculum, mySci, uses the 5E instructional model. Teachers perceive the unit coherence during a 5E instructional unit. In OpenSciEd instructional units, students perceive coherence. Trends in data suggest that students experiencing OpenSciEd have higher academic achievement than students experiencing mySci. There were more interesting trends in the attitudes toward science as measured by the MATS survey (Hillman, et al., 2016). Greater gains were seen by the OpenSciEd group, but in some domains in which a gain would not be wanted. Both groups showed a decrease in their desire to become a scientist. We hope that the results of this investigation can be used to further explore differences in two inquiry-based curricula as a way to help educators and school districts make informed decisions about curriculum implementation.

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Appendices

Appendix A

NGSS Standards Alignment Comparison

<table>
<tr><th>mySci, module 11: How can we as space scientists analyze data to plan a space?</th><th>OpenSciEd, unit 8.4: How are we connected to the patterns we see in the sky and space?</th></tr>
<tr><td colspan="2">NGSS Performance Expectations (PEs)</td></tr>
<tr><td colspan="2">MS-ESS1-1: Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.</td></tr>
<tr><td colspan="2">MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.</td></tr>
<tr><td colspan="2">MS-ESS1-3: Analyze and interpret data to determine the scale properties of objects in the solar system.</td></tr>
<tr><td></td><td>MS-PS2-4: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.</td></tr>
<tr><td colspan="2">Focal Disciplinary Core Ideas (DCIs)</td></tr>
<tr><td colspan="2">ESS1.A: The Universe and its Stars</td></tr>
<tr><td colspan="2">Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.</td></tr>
</table>

mySci, module 11: *How can we as space scientists analyze data to plan a space?*	OpenSciEd, unit 8.4: *How are we connected to the patterns we see in the sky and space?*
Focal Disciplinary Core Ideas (DCIs)	
ESS1.B: Earth and the Solar System	
The solar system consists of the Sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the Sun by its gravitational pull on them. This model of the solar system can explain eclipses of the Sun and the Moon. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the Sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.	
PS2.B: Types of Interactions	
	Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the Sun.
PS4.B: Electromagnetic Radiation	
	A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

mySci, module 11: *How can we as space scientists analyze data to plan a space?*	OpenSciEd, unit 8.4: *How are we connected to the patterns we see in the sky and space?*
Focal Science and Engineering Practices (SEPs)	
Developing and Using Models*	Developing and Using Models
Using Mathematics and Computational Thinking*	Analyzing and Interpreting Data
	Obtaining, Evaluating and Communicating Information
Focal Crosscutting Concepts (CCCs)	
Patterns*	Patterns
Scale, Proportion, and Quantity*	Scale, Proportion, and Quantity
	System and System Models

Note. Items with * were identified based on an external review by K. Rademaker of the mySci unit using the EQuIP Rubric for Science, version 3.1 (EQuIP, 2021).

Appendix B

mySci Module 11 and OpenSciEd Unit 8.4 Pre-/Posttest

Name ______________________________ Unique ID ___________

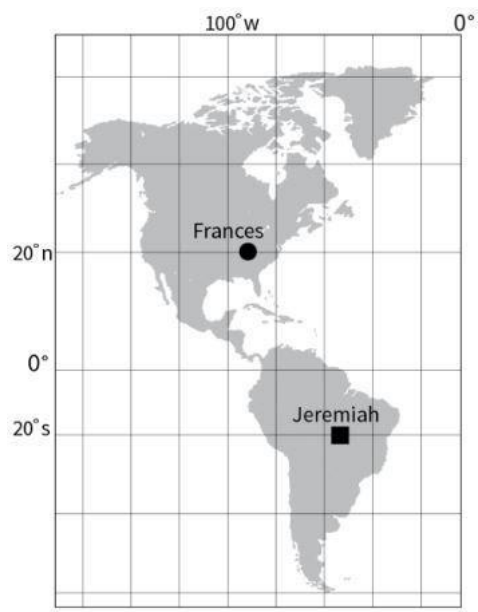
Date ______________________________ Section ________________

Section 1: Seasons

1. Earth's seasons are caused by which of the following, in addition to Earth's revolution around the Sun?

   A. The tilt of Earth's axis of rotation
   B. The varying amount of sunspot activity throughout the year
   C. The elliptical shape of Earth's orbit around the Sun
   D. The rotation of Earth during a 24-hour day

Scenario 1: Frances lives in the Northern hemisphere, at location A. Jeremiah lives in the Southern hemisphere, at location B. Frances and Jeremiah are friends, and often talk on the phone. Early one morning, the two are on the phone, and Jeremiah describes how he is sitting at the beach watching the sunrise. Frances explains that it is still dark where she lives.



2. Explain why Jeremiah would experience both sunrise and moonrise before Frances. Use your understanding regarding the patterns of the apparent motion of the sun in the sky, to support your answer.

Jeremiah decided he wanted to visit Frances. They discuss whether they should have the visit during June or December. Jeremiah suggests December, so they can enjoy being outside together. However, Frances says it would be better to visit in June.

3. Explain why it might be better for Jeremiah to visit Frances during June by explaining what Frances and Jeremiah would observe during the months of June and December where Frances lives. Be sure to include the following in your answer:

- The season they would experience in each month
- Approximately how long the days would be in each month
- Where the sun would be in the sky compared to the horizon in each month

4. Draw a model to explain the seasonal patterns Jeremiah and Frances observe.

- Model the Earth-Sun relationship during the month of June. Include in your model the Sun, Earth, tilted axis, rotation and revolution.
- Explain how this model affects the seasons where Frances lives and Jeremiah lives.
- Model the Earth-Sun relationship during the month of December. Include in your model the Sun, Earth, tilted axis, rotation and revolution.
- Explain how this model affects the seasons where Frances lives and Jeremiah lives.

Month	Model	Explanation
June		
December		

Scenario 2: In Australia there are many different seasons, such as Wombat season and Biderap season. During the Wombat season, Wombats emerge from their dens, which is from April through July, the days are short, nights are long, and the temperature is cooler. During Biderap season, when brown butterflies emerge, which is in January and February, the days are longer, nights are shorter, and the temperature is hotter.

Dmitry Brant

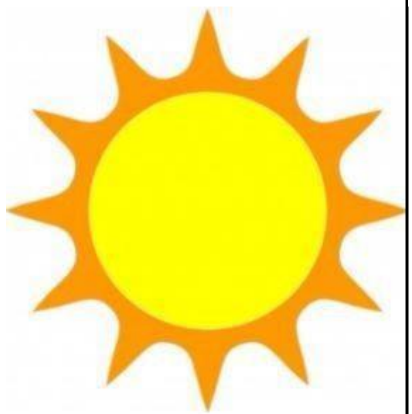
CSIRO

Examine the data below, which shows the average low and high temperatures in Melbourne, Australia.

Month and season	**Average high temp. in Melbourne, Victoria, Australia**	**Average low temp. in Melbourne, Victoria, Australia**
July, Wombat season	57°F (13.9°C)	45°F (7.2°C)
January, Biderap season	79°F (26.1°C)	60°F (15.5°C)

5. What causes seasonal temperature variation between Wombat season (July) and Biderap season (January) in Australia?

6. Using words, and/or pictures, support your explanation using the temperature data above, your Gotta-Have-It Checklists, and by completing the model below.

Wombat season: July		Biderap season: January
	 Sunshine by Clipart.info is licensed under CC BY 4.0	

We all live on the same Earth, yet at the same time of year people might have very different experiences of the climate in different places on Earth. Professor Medupe and Jessie both mentioned in their podcasts that the cooler months where they live happen during what we would call summer or the warmer months in the Northern Hemisphere. For example, in July someone in the United States might be experiencing warmer weather and long days while a person in Australia might be experiencing really colder weather and short days. See the data table below for example temperatures in the Northern and Southern Hemispheres during January and July.

Month	**Average high temp. in Melbourne, Victoria, Australia (Southern Hemisphere)**	**Average high temp. in Seattle, Washington, United States (Northern Hemisphere)**
July	57°F (13.9°C)	72°F (22.2°C)
January	79°F (26.1°C)	47°F (8.3°C)

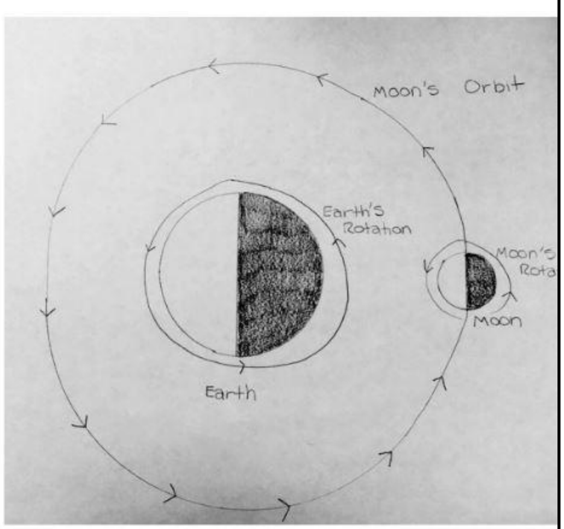
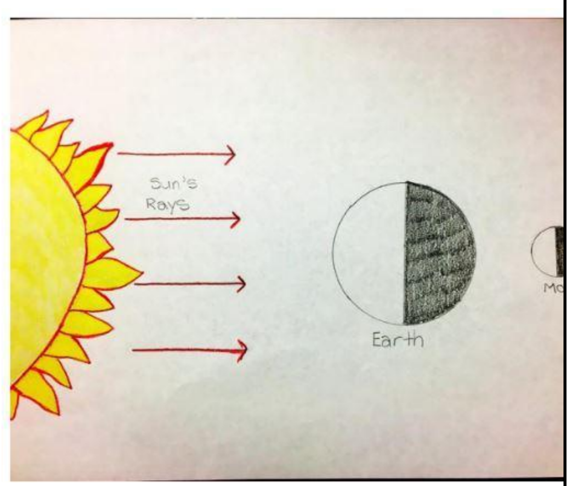
7. Why do the warmer months in the United States occur at the same time as the cooler months in Australia and the cooler months in the United States align with the warmer months in Australia?

Section 2: The Moon

Scenario 3: Marisa is camping with her family. She and her sister, Brianna are looking at the night sky. They observe the moon rise along the eastern horizon. They snap the following picture as the moon moves through the night sky:

8. Which phase of the moon was observed?
    A. full
    B. quarter
    C. waning gibbous
    D. new

Marisa brings the image back to her science class when she returns to school, and the teacher asks the class to develop models that show the Earth-moon-sun system that would cause this phenomena. Below are 2 models the students developed.

Figure A.	Figure B.
	

9. Compare and contrast the models. What is similar and different about the models?

10. Choose one of the models to revise. In the space below draw a more accurate model of what causes the phase of the moon Marisa and her sister observed. Explain how the change that you made and why this model is an improvement.

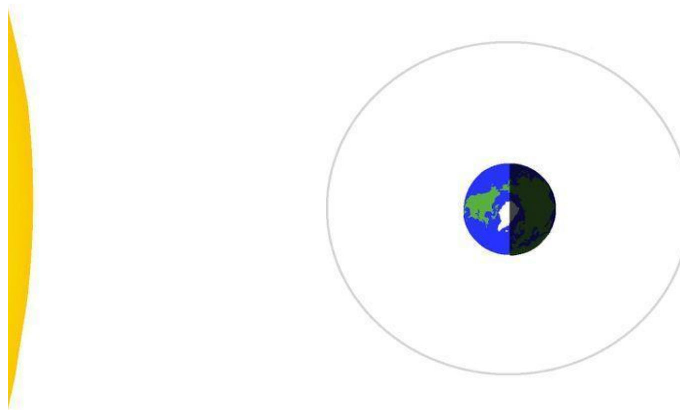
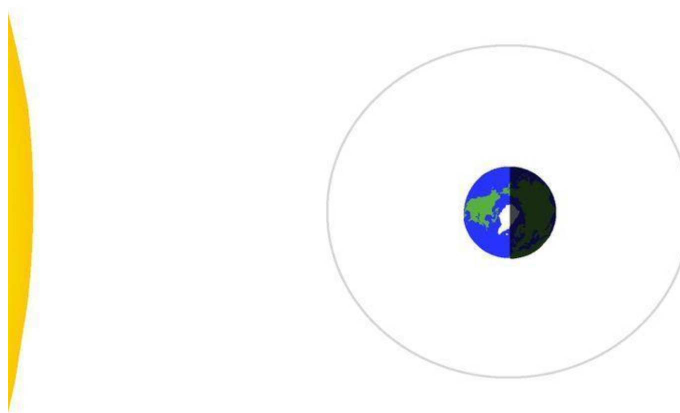
11. Marisa and her sister would like to continue to track and photograph the moon. About how much time will it take for the moon to be in this position again?

A. one week
B. two weeks
C. one month
D. one year

12. Based on your revised model, what causes the phases of the moon?

A. the Earth's daily rotation on its axis
B. the moon's monthly rotation on its axis
C. the position of the moon with respect to the Earth and the sun
D. all of the above

Scenario 4:

Shape Patterns of Earth-Sun-Moon System		
Image of the Moon (in the sky)	Description of the shape of Moon we see	Complete the model of the Earth-Sun-Moon system to explain why the Moon looks that way. ● Add the location of the Moon on the circle that represents the orbit of the Moon. ● Show the lit and unlit halves of the Moon. ● Add an observer on the Earth.
 NASA's Scientific Visualization Studio		
 NASA's Scientific Visualization Studio		

Appendix C

Modified mySci Module 11 and OpenSciEd Unit 8.4 Pre-/Posttest

Name: Unique ID:

Date: Section

Modifications are described in **bold**. Determination of use of a section is described in *italics*.

SEASONS

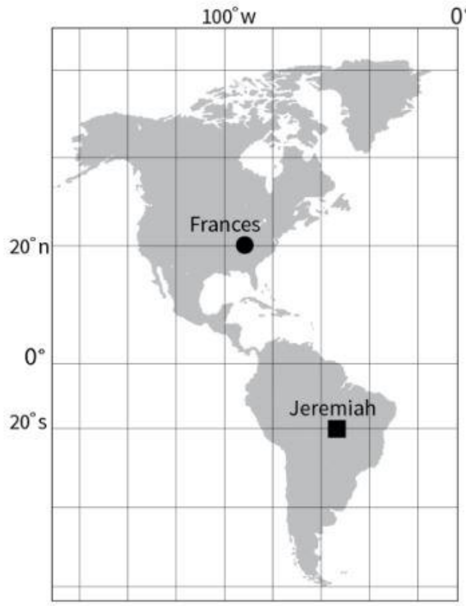
Determination: This section was removed as the majority of modified items either gave students too much information or provided partial understandings which reduced the ability to assess students' understanding of the PE. The remaining items were not enough to allow for accurate assessment of students' understanding of the PE.

FROM mySci pre-/posttest:

1. Earth's seasons are caused by which of the following, in addition to Earth's revolution around the Sun?
    A. The tilt of Earth's axis of rotation
    B. The varying amount of sunspot activity throughout the year
    C. The elliptical shape of Earth's orbit around the Sun

Modification: removed one choice

Scenario 1: Frances lives in the Northern hemisphere, at location A. Jeremiah lives in the Southern hemisphere, at location B. Frances and Jeremiah are friends, and often talk on the phone. Early one morning, the two are on the phone, and Jeremiah describes how he is sitting at the beach watching the sunrise. Frances explains that it is still dark where she lives.



2.Choose the best answer that explains why Jeremiah would experience both sunrise and moonrise before Frances.

A. The sun and moon appear in a western location first.
B. The sun and moon appear in an easterly location first.
C. The sun and moon appear in a northern location first.

Modification: Item converted into multiple choice from free response.

Jeremiah decided he wanted to visit Frances. They discuss whether they should have the visit during June or December. Jeremiah suggests December, so they can enjoy being outside together. However, Frances says it would be better to visit in June.

3. Choose the best answer that explains why it might be better for Jeremiah to visit Frances during June by explaining what Frances and Jeremiah would observe during June where Frances lives.

A. If Jeremiah visits Frances during June, they would experience winter with a maximum amount of daylight hours.
B. If Jeremiah visits Frances during June, they would experience winter with a minimum amount of daylight hours.
C. If Jeremiah visits Frances during June, they would experience summer with maximum amount of daylight hours.

Modification: Item converted into multiple choice from free response.

4. Draw a model to explain the seasonal patterns Jeremiah and Frances observe.

- Model the Earth-Sun relationship during the month of June. Include in your model the Sun, Earth, tilted axis, rotation and revolution.
- Explain how this model affects the seasons where Frances lives and Jeremiah lives.
- Model the Earth-Sun relationship during the month of December. Include in your model the Sun, Earth, tilted axis, rotation and revolution.
- Explain how this model affects the seasons where Frances lives and Jeremiah lives.

Month	Model	Explanation
June		
December		

FROM OpenSciEd Lesson 4:
What causes the seasons in Australia and why are they opposite of our seasons?

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Scenario 2: In Australia there are many different seasons, such as Wombat season and Biderap season. During the Wombat season, Wombats emerge from their dens, which is from April through July, the days are short, nights are long, and the temperature is cooler. During Biderap season, when brown butterflies emerge, which is in January and February, the days are longer, nights are shorter, and the temperature is hotter.

Examine the data below, which shows the average low and high temperatures in Melbourne, Australia.

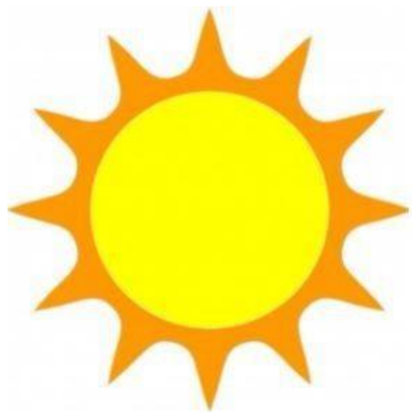
Month and season	**Average high temp. in Melbourne, Victoria, Australia**	**Average low temp. in Melbourne, Victoria, Australia**
July, Wombat season	57°F (13.9°C)	45°F (7.2°C)
January, Biderap season	79°F (26.1°C)	60°F (15.5°C)

5. What causes seasonal temperature variation between Wombat season (July) and Biderap season (January) in Australia?

Seasonal variation is caused by the earth's __________ on its tilted __________ with respect to its ____________ plane.

Modification: Item converted into fill in from free response.

6. Using words, and/or pictures, support your explanation using the temperature data above, your Gotta-Have-It Checklists, and by completing the model below.

Wombat season: July		Biderap season: January
	 Sunshine by Clipart.info is licensed under CC BY 4.0	

We all live on the same Earth, yet at the same time of year people might have very different experiences of the climate in different places on Earth. Professor Medupe and Jessie both mentioned in their podcasts that the cooler months where they live happen during what we would call summer or the warmer months in the Northern Hemisphere. For example, in July someone in the United States might be experiencing warmer weather and long days while a person in Australia might be experiencing really colder weather and short days. See the data table below for example temperatures in the Northern and Southern Hemispheres during January and July.

Month	Average high temp. in Melbourne, Victoria, Australia (Southern Hemisphere)	Average high temp. in Seattle, Washington, United States (Northern Hemisphere)
July	57°F (13.9°C)	72°F (22.2°C)
January	79°F (26.1°C)	47°F (8.3°C)

7. Why do the warmer months in the United States occur at the same time as the cooler months in Australia and the cooler months in the United States align with the warmer months in Australia?

The earth is _________ 23.5° on its axis so that when the Northern Hemisphere is tilted towards the sun, receiving ________ direct sunlight, and the Southern Hemisphere is tilted ____________ the sun, receiving indirect sunlight. Solar elevations are ____________ in the Northern and Southern Hemispheres at the same time (July or January). Light ___________ amounts reaching the surface are directly related to solar elevations. _____________ is directly related to light energy amounts reaching the surface.

Modification: Item converted into fill in from free response.

MOON

Determination: Item 9 was removed as the modification gave students too much information which reduced the ability to assess students' understanding of the PE. Items 8, 10, 11, 12, image 1 and image 2 were used to assess students' understanding of the PE.

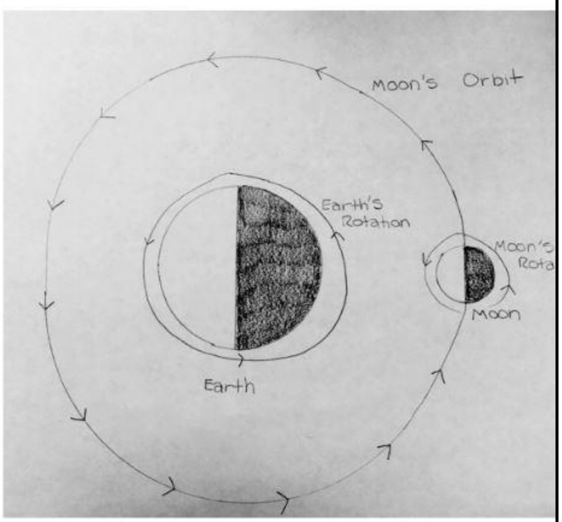
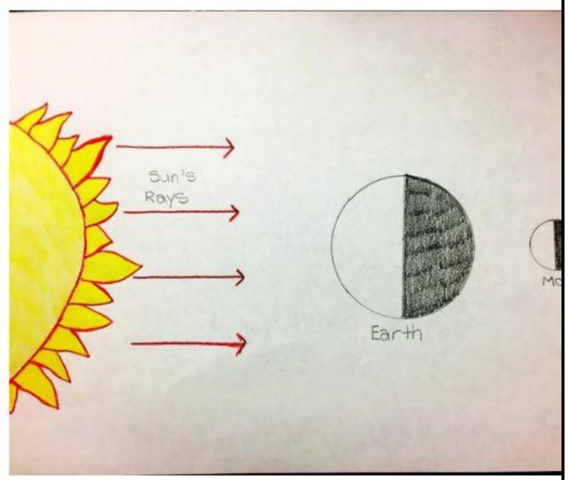
FROM mySci pre-/posttest:

Scenario 3: Marisa is camping with her family. She and her sister, Brianna are looking at the night sky. They observe the moon rise along the eastern horizon. They snap the following picture as the moon moves through the night sky:

8. Which phase of the moon was observed?
   A. full
   B. quarter
   C. waning gibbous

Modification: one choice removed

Marisa brings the image back to her science class when she returns to school, and the teacher asks the class to develop models that show the Earth-moon-sun system that would cause this phenomena. Below are 2 models the students developed.

Figure A.	Figure B.
	

9. Compare and contrast the models. What is similar and different about the models? Fill in the blanks.

   Figure A above shows the Earth ___________ on its axis. It also shows the moon _________________ around the Earth. Figure B shows the Sun, light from the Sun, the Earth, and the moon in ______________ moon position.

Modification: Item converted into fill in from free response.

10. Choose one of the models to revise. In the space below draw a more accurate model of what causes the phase of the moon Marisa and her sister observed. Explain how the change that you made and why this model is an improvement.

11. Marisa and her sister would like to continue to track and photograph the moon. About how much time will it take for the moon to be in this position again?
   A. one week
   B. two weeks
   C. one month

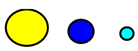
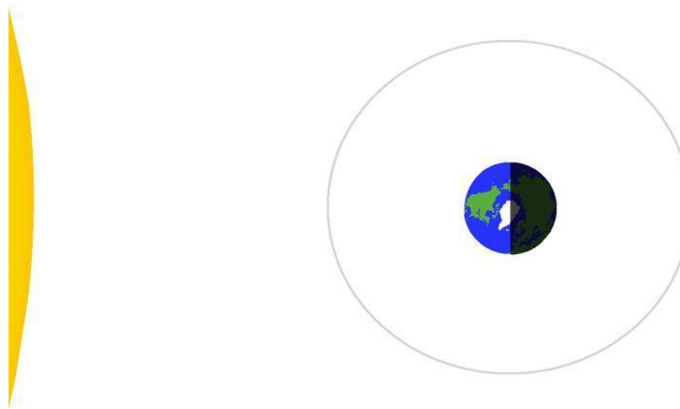
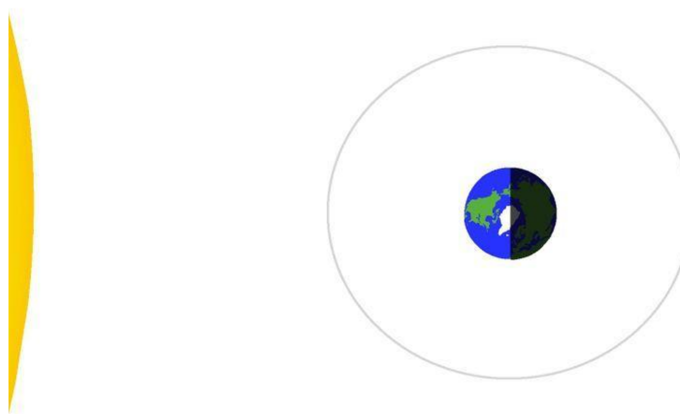
Modification: one choice removed

12. Based on your revised model, what causes the phases of the moon?
    A. the Earth's daily rotation on its axis
    B. the moon's monthly rotation on its axis
    C. the position of the moon with respect to the Earth and the sun

Modification: one choice removed

FROM OpenSciEd Lesson 6:

Scenario 4:

Shape Patterns of Earth-Sun-Moon System		
Image of the Moon (in the sky)	Description of the shape of Moon we see	Complete the model of the Earth-Sun-Moon system to explain why the Moon looks that way. ● Add the location of the Moon on the circle that represents the orbit of the Moon. ● Show the lit and unlit halves of the Moon. ● Add an observer on the Earth.
 NASA's Scientific Visualization Studio	 Sun Earth Moon	
 NASA's Scientific Visualization Studio		

Appendix D

My Attitudes Toward Science Survey

1. Scientists do not criticize other scientists' work.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

2. I usually understand what we are talking about in science.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

3. Scientists work alone.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

4. People do not need to understand science because it does not affect their lives.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

5. No matter how I try, I cannot understand what the teacher is describing in science class.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

6. It makes me nervous to even think about being in a science class.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

7. Science is easy for me.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

8. Discoveries in science do not affect how I live.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

9. Studying science is something that I enjoy very much.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

10. I do not do very well in science.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

11. I would like a job as a scientist.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

12. Our world is nicer to live in because of science.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

13. Scientists work in labs.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

14. You have to be old to be a scientist.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

15. I often think, "I cannot do this," when science is being taught.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

16. You have to be at least a little bit crazy to be a scientist.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

17. Scientists do not try to improve upon an explanation they have discovered about the world.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

18. Most students seem to understand science.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

19. Science is not useful to anyone but scientists.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

20. It scares me to have to study science.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

21. Scientists are males.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

22. Scientists do not have enough time to have fun.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

23. Science is one of my favorite subjects.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

24. I have a good feeling toward science.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

25. Only thinking is important to scientists, not how they feel about something.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

26. Science discoveries do not help people live better.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

27. A country could be strong even if it has no scientists.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

28. I like science classes.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

29. People should understand science since it is an important part of their lives.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

30. I don't want a job as a scientist, because I have no interest in it.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

31. I feel upset when someone talks to me about being in a science class.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

32. The things scientists discover through their work do not affect other people in my life.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

33. In their work, scientists report exactly what they observe.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

34. Science helps solve the problems of everyday life.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

35. Scientists wear lab coats.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

36. Science is hard for most students to understand.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

37. If one scientist says an idea is true, all other scientists will believe it.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

38. Technology is an example of an important product of science.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

39. A major purpose of science is to produce new drugs and save lives.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

40. Science is helpful to understand the world.

( ) Disagree a lot
( ) Disagree a little
( ) Have not decided
( ) Agree a little
( ) Agree a lot

Appendix E

Student Assent Form

UMSL

Department of Education

One University Boulevard
St. Louis, Missouri 63121-4499
Telephone: 314-516-6220
E-mail: grangerch@umsl.edu

Assent to Participate in Research Activities (Minors)

Comparison Between the Effectiveness of MySci 5E and OpenSciEd Curricula on the Achievement and Attitudes of Eighth Grade Students

1. Our names are Nina Blanton and Nicole Vick.

2. I am asking you to take part in a research study because we are trying to learn more about how your science course affects your achievement in science and how you feel (your attitudes) about science.

3. If you agree to be in this study, you will be asked to take a pre- and posttest measuring how well you do on a science unit assessment and a pre- and post-survey about your feelings toward science. The tests will take 45 minutes or less, and you will take it before and after a unit on sound in your science class while your science teacher monitors you. The surveys will take 30 minutes or less, and you will take it before and after a unit on sound in your science class while your science teacher monitors you.

4. Being in this study will not harm you in any way.

5. You will probably not get any direct benefits from being in this study, but you might enjoy knowing that your honest answers will help teachers choose a science course that excites you more about learning science, helps you realize the usefulness of science in the real world, and help you feel more confident about learning science.

6. Please talk this over with your parents before you decide whether to participate. I also will ask your parents to
give their permission for you to take part in this study. Even if your parents say "yes," you still can decide not to do this.

7. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you, and no one will be upset if you don't want to participate or if you change your mind later and want to stop.

8. You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can call us at 314-753-6332 (Nina Blanton) or 309-397-3213 (Nicole Vick).

9. Signing your name at the bottom means that you agree to be in this study. You and your parents will be given a copy of this form after you have signed it.

____

Participant's Signature Date Participant's Printed Name

____

Parent or Guardian's Signature Date Parent or Guardian's Printed Name

________________ ____________________

Participant's Age Grade in School

Appendix F

Parental Consent Form

UMSL

Department of Education

One University Boulevard
St. Louis, Missouri 63121-4499
Telephone: 314-516-6220
E-mail: grangerch@umsl.edu

Informed Consent for Participation in Research Activities
Comparison Between the Effectiveness of MySci 5E and OpenSciEd Curricula on the Achievement and Attitudes of Eighth Grade Students

Participant ____ IRBNet Approval Number ___________________

Principal Investigators Nina Blanton / Nicole Vick PI's Phone Number 314-753-6332 / 309-397-3213

Summary of the Study

The general purpose is to investigate the impact of a NGSS storyline unit, referred to as OpenSciEd 8.2 How can sound make something move?, on the science achievement and students' attitude toward science in eighth grade science students. We plan to determine if this instructional method could serve as a model for enhancing student interest and academic achievement in science.

Neither the statistical analyses of anonymous achievement scores by the researchers nor the completion of an online survey measuring student motivation to learn mathematics by participants poses a significant risk to the physical, psychological, social, economic, or legal well-being of the participants.

We will take multiple precautionary measures to protect the privacy of participants. As part of this effort, the identity of participants will not be revealed in any publication or presentation that may result from this study. All identifying information will be removed from the achievement score data so that at no time will the researchers be able to identify a particular student, their scores, or their participation in this study. The anonymous achievement score data will be stored securely for a period of up to three years on password protected computers that operate behind a firewall and are only accessible by the researchers and their employers' system administrators. After three years, all achievement score data will be permanently deleted. The online motivation survey will be taken anonymously on a secure network with no collection of identifying information, therefore, individual responses to specific survey questions will not be identifiable.

1. Your child is invited to participate in a research study conducted by Nina Blanton, Nicole Vick, and Dr. Charles Granger (faculty advisor). The purpose of this research is to measure the impact of your child's current science course on their science achievement and attitude towards science.

2. a) Your child's participation will involve:

- Your child completing an online survey designed to measure student attitudes toward science, before and after completion of the units being studied. The survey consists of rating your opinion to several items on a scale of 1 to 5. This activity is in addition to normal classroom activities, and is <u>not a part of normal classroom activities</u>.
- Your child completing a pre- and posttest unit assessment designed to measure student achievement of science concepts explored in the two units being studied. This activity is a part of <u>normal classroom activities</u>. This data will be collected for research purposes.
- Approximately 150 students may be involved in this research. The research will be conducted in eighth grade science classrooms at Ferguson Middle School within the Ferguson-Florissant School District.

b) The amount of time involved in your child's participation will be approximately 30 minutes to complete the online survey during two regular class periods of their science course under the direct supervision of their regular classroom teacher and approximately 45 minutes to complete the pre- and posttests during two regular class periods of their science course under the direct supervision of their regular classroom teacher.

c) Your child may either be in a classroom using the school district adopted science curriculum, mySci, or an alternative, equivalent science curriculum, OpenSciEd. The selection of which classrooms receive either curriculum will be chosen to ensure that there are similar numbers of students experiencing either curricula.

3. All studies contain some level of risk. For this study, there is a risk of loss of student confidentiality. To help reduce this risk, students will be provided with identifiers using a free program (Brenz.net, random ID generator). These will be different from the student identification number used by the school in the study.

4. There are no direct benefits for your child's participation in this study. However, your child's participation will contribute to the knowledge about the effectiveness of certain instructional models for learning science and enhancing student attitudes towards science. This knowledge could lead to students being better prepared to pursue careers in science, technology, engineering, and math.

5. Your child's participation is voluntary and you may choose not to let your child participate in this research study or to withdraw your consent for your

child's participation at any time. Your child may choose not to answer any questions that he or she does not want to answer in regards to the online survey designed to measure student attitudes toward science. You and your child will NOT be penalized in any way should you choose not to let your child participate or to withdraw your child.

6. We will do everything we can to protect your child's privacy. As part of this effort, your child's identity will not be revealed in any publication or presentation that may result from this study. In rare instances, a researcher's study must undergo an audit or program evaluation by an oversight agency (such as the Office for Human Research Protection). That agency would be required to maintain the confidentiality of your child's data.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigators, Nina Blanton (314-753-6332), Nicole Vick (309-397-3213), or the Faculty Advisor, Dr. Charles Granger (314-516-6220). You may also ask questions or state concerns regarding your child's rights as a research participant to the Office of Research Administration, at 314-516-5897.

I have read the above statement and have been able to express my concerns, to which the investigator has responded satisfactorily. I believe I understand the purpose of the study, as well as the potential benefits and risks that are involved. I authorize the use of my PHI and give my permission to participate in the research described above.

All signature dates must match.

____ ____

Parent or Guardian's Signature Date Parent or Guardian's Printed Name

____

Child's Printed Name

____ ____

Signature of Investigator or Designee Date Investigator or Designee Printed Name

Appendix G

Tests for Normality Results of Pre- and Post-Instructional Mean MATS Survey Scores for Desire

Group 0 is the mySci group. Group 1 is the OpenSciEd group.

Pre-instructional tests for normality results

Variable: pre_d_mean (pre_d_mean)
Group = 0

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.741685	**Pr < W**	<0.000
Kolmogorov-Smirnov	**D**	0.298981	**Pr > D**	<0.010
Cramer-von Mises	**W-Sq**	0.502609	**Pr > W-Sq**	<0.005
Anderson-Darling	**A-Sq**	2.793225	**Pr > A-Sq**	<0.005

Variable: pre_d_mean (pre_d_mean)
Group = 1

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.789981	**Pr < W**	0.0015
Kolmogorov-Smirnov	**D**	0.278477	**Pr > D**	<0.0100
Cramer-von Mises	**W-Sq**	0.224372	**Pr > W-Sq**	<0.0050
Anderson-Darling	**A-Sq**	1.41389	**Pr > A-Sq**	<0.0050

Post-instructional tests for normality results

Variable: post_d_mean (post_d_mean)
Group = 0

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.769137	**Pr < W**	<0.0001
Kolmogorov-Smirnov	**D**	0.285651	**Pr > D**	<0.0100
Cramer-von Mises	**W-Sq**	0.373018	**Pr > W-Sq**	<0.0050
Anderson-Darling	**A-Sq**	2.222445	**Pr > A-Sq**	<0.0050

Variable: post_d_mean (post_d_mean)
Group = 1

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.891728	**Pr < W**	0.0495
Kolmogorov-Smirnov	**D**	0.189124	**Pr > D**	0.1024
Cramer-von Mises	**W-Sq**	0.106364	**Pr > W-Sq**	0.0875
Anderson-Darling	**A-Sq**	0.71472	**Pr > A-Sq**	0.0501