TRANSMEDIA STEM INTERVENTION BOOK IN MIDDLE SCHOOL FOR EDUCATIONAL CHANGE

Alicia Stansell

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APPROVED:
Tandra Tyler-Wood, Major Professor
Bill Elieson, Co-Major Professor
Demetria Ennis-Cole, Committee Member
Costas Tsatsoulis, Dean of the Toulouse
Graduate School

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The world is becoming a global place in which science, technology, engineering and mathematics hold a key to a successful future. To help secure this future it is important to engage students early with relevant curriculum that sparks interest and success in STEM fields. However, education reform occurs slowly, so this paper looked at a potential paradigm that can help to bring about change in a middle school environment that harnesses the long standing strengths of learning and education with the integration of technology to create changes in the pedagogy of learners and teachers. The study implemented a transmedia STEM book and evaluated the impact it had on student perceptions of STEM, school attitude, academic achievement, and preferred activity types, providing an example vehicle for change that can be adopted over time. The main findings showed that students who used a 3-Dimensional printer had higher math achievement and a more positive perception of math.

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CHAPTER 1

INTRODUCTION

Introduction to the Problem

The education of America’s youth is falling short. Two-thirds of American students are not prepared for what comes after high school, be it a career or more school (Vander Ark, 2013). In 2000, Parsad and Lewis (2003) found that 76% of degree-granting 2- and 4-year colleges had to offer remedial courses to help students achieve readiness for college. While the number of first-year college freshmen who reported taking a remedial course dropped from an average of 26% in 2000 to an average of 20% in 2008 (Sparks & Malkus, 2013), as a country, there is still work to do in preparing the next generations for what comes after their compulsory education. To help students graduate, and help the nation become more globally competitive, students need to enter college ready to learn with an idea of what career they want to pursue. As students move through their K-12 years, it is important to engage them in school and career planning. Future and career planning has been included in curriculum planning for several decades, as this area has historically been an area of struggle for students (Phipps & Evans, 1968).

There are many factors that impact changing educational structures and environments in the United States. Culture, structure, and social interactions all shape the changes that will occur in a school environment (Priestley, 2010). For change to occur, teachers need support from external entities, such as political arenas (Burkhardt, 2014). An area of educational curriculum reform that has received support in the political and vocational settings is a cohesive interdisciplinary curriculum of Science, Technology, Engineering, and Mathematics (STEM).

As the world continues to compete economically on a global scale, there will be a continued push in the educational environment for STEM (Williams, 2011; Ejiwale, 2012; The

White House, Office of the Press Secretary [press release], 2013). However, the United States ranks 20th worldwide for students completing college with a four-year engineering degree, slowly making the nation less globally competitive since 2001 (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011). This downward trend must change. A barrier to this change is that existing educational curriculum is long established and difficult to sway, despite STEM implementation in schools receiving increased political attention (Williams, 2011). Even though change occurs slowly or not at all, STEM integration still persists in being a goal for greater integration into schools, as it promotes a promise of a better future for the United States vocationally and economically (Carnevale, Smith, & Melton, 2011; Williams, 2011; Newcombe, 2010). The desire for the nation to become more globally competitive in STEM fields can be seen by organizations such as the National Science Foundation providing grants to encourage STEM curriculum integration into schools (Herschbach, 2011; Stansell, Quintanilla, Zimmerman, & Tyler-Wood, 2015).

Starting early to encourage STEM engagement is imperative. Targeting middle school is key since these students tend to disengage. Middle school is a time when students may lose interest in the college and STEM trajectory if they are not engaged during that time and put on track for these fields in middle school and beyond (Williams, Kirst, & Haertel, 2010). Therefore, students need support and encouragement to develop a personal interest in STEM (Hall et al., 2011). A key factor in developing an interest, selecting a major of study, or career path in a particular field is exposure to that content and area of study (Hall, et. al. 2011). A curriculum intervention at the middle school level is needed to encourage a positive attitude toward school, increase STEM interest, and academic gains, as well as outline the types of activities that can help bring about these changes.

Dissertation Overview

The last decades of the 20th century created a technologically driven singularity that sparked the digital potential of education (Prensky, 2001). Key initiatives in the 1970s include the following: Project Gutenberg, providing free electronic books (Lebert, 2004); Britain's Prestel service of videotex (Gunter, 2003); and the British Broadcasting Corporation's Ceefax television subtitling (Gunter, 2003) that helped to lay a foundation for the evolution of the education environment into a connected transmedia world. A transmedia world is fluid and dynamic in nature because it can pull from the strengths of a variety of media to interactively communicate complex messages (Lamb & Johnson, 2010). Even fundamental activities like reading a book are being redefined by the innovation of the digital age (Lamb, 2011).

Digital age innovations extend into curriculum innovations that should include a variety of media, which can be difficult to support in a classroom with out-of-date equipment, requiring a sustained effort and long-term investment to continue updating the curriculum (Center for the Study of Mathematics, 2012). One such educational innovation recognized at the National Technology Leadership Summit (2011) is transmedia books that, "…[have] many characteristics of a traditional book but can transform digital images and designs in [their] pages into physical objects" (McPherson, 2011). These physical objects transform from a two-dimensional (2-D) form into a three-dimensional (3-D) form through the use of 2-D fabricators and 3-D printers.

A transmedia book also provides a framework that allows students to utilize new or old technologies to solve problems in a way that can engage students throughout a different curriculum than they would normally experience. The change of curriculum that a transmedia book offers is one way to introduce interventional curriculum to help bring about a change in the way STEM is implemented in the classroom. Before innovations like transmedia books can be generalized, their use should be tested in limited situations, while also meeting the needs of a very diverse student populace. Even though the world has been rapidly innovating technology, educational change has occurred slowly (Priestley, 2010) Educational change should be based on a firm understanding of learning and technology philosophy, theory, history, and future goals. The literature review will discuss the philosophy of the proposed intervention, the historical development of the media and the potential educational impact to help support the adoption of transmedia into middle school classrooms.

Overview of Study

This study takes a quantitative look at a specific transmedia STEM intervention curriculum used in middle school classes. This is an experimental study framework with a post-positivist epistemology, in that through an experimental methodology, the findings are probably true but from a probabilistic standpoint (Aliyu, Bello, Kasim, & Martin, 2014). The transmedia book, *Engineers Needed: Help Tamika Save the Farm!,* will be used in the classrooms of a public middle school. All students in the participating classrooms will experience the same learning environment, though some groups will experience the use of the 3-D printer during the experimental time. A quantitative static group pretest-posttest design (Fraenkel, Wallen, & Hyun, 1993, p. 270) will be used to measure whether or not there are changes in the students' academic achievement, STEM or school perceptions, and activity preference as a result of the intervention curriculum. The quantitative instruments that will be used are the STEM Semantics Survey, the Career Interest Questionnaire formatted for both math and science, the School Attitude Assessment Survey–Revised, activity rankings through paired comparisons, and a locally developed academic test adapted from previously released Trends in International Mathematics and Science Study (TIMSS) questions.

Statement and Purpose

The United States is falling behind in STEM college graduation rates and employee workforce compared to the rest of the world. The trend can be seen through students becoming less competitive in math and science achievement via comparisons done in studies such as Trends in International Mathematics and Science Study. Middle school is a developmentally critical place for students that could help set students on a path to success. The question becomes what type of innovations in the middle school curriculum will be the least invasive for teachers, students, and administrators while having the greatest impact on fostering positive student outlooks on STEM. This study provided a short-term option that strived to create a long-term change with new STEM integrated curriculum. The purpose of this study was to investigate the impact of a STEM intervention transmedia book on students in a public middle school. The study provided insight into student’s perception of STEM, school attitude, academic growth, and preferred STEM activities in a middle school STEM curriculum. The insight gained from this study attempted to address Roblyer and Knezeks’ (2003) future research for technology integration agendas by providing the rationale for transmedia use and the relative advantages it can provide, while helping to improve the future implementation of these technologies to address the societal goal of more STEM graduates.

Research Questions

STEM is being integrated in the middle school classrooms in different ways. The method of STEM integration for this study used a transmedia book medium as a short-term STEM intervention. Students used different types of media to design, create, and fabricate solutions to real-life agriculture problems presented to them in the transmedia book: *Engineers Needed: Help Tamika Save the Farm!* With any educational change, it is important to address questions about the potential impact before expanding the intervention. The study attempted to address the following questions:

a. Did students perceptions of STEM change after experiencing a STEM intervention curriculum?

b. Did students have a change in their STEM interest as a career through this STEM intervention curriculum?

c. Did students have a different attitude towards school after experiencing the STEM intervention curriculum?

d. What kind of STEM activities did students value the most?

e. What kind of academic achievement/gains could be seen from implementing a STEM unit?

Quantitative with Limitations

The participants could not be recruited through random sampling into their middle school classes so a pretest and posttest was used to see any changes across the different groups. The number of students in the participating STEM elective varies from year to year. The total number of participants was 69 seventh grade students. Therefore, the results are not easily or accurately generalized. Furthermore, the selection or placement in this elective brought with it a pre-disposition to the STEM subjects. Basic demographics were gathered to help compare similarities and differences across the groups. A repeat measures ANOVA was used to help compare changes in the groups across the different instruments. The participants were taken from an existing seventh-grade STEM elective, where students were in their first-year of a STEM elective. The year prior to the study, all of the approximately 250 sixth-grade students in the school had the opportunity to apply to the STEM elective class for their seventh-grade year. The application entailed bringing a form signed by the student and parent to show informed course interest. The average percent of students applying to the elective is 25% of the student class. The school district recently increased funding to allow all sixth-grade students the opportunity to be able to participate in the class. Any selection process for the students in a given class period was handled by the counselors on a stratified random sample based on all scheduling availability and max class sizes. The students who participated may have experienced a glass ceiling impact, in that they had pretests that already showed a high level of interest, academic achievement, and positive school attitude, so very little difference was seen from pretest to posttest after the 20 hour intervention.

Definition of Terms

Two-dimensional (2-D) – an object that has only two dimensions of measurement, such as length and width (Two–dimensional, 2015)

2-D printer –a device that using a small blade to cut the length and width of a digitally designed object through a combination of ink, solid cuts, and perforated edges to allow easy folding into a 3-D object that has width, length, and height.

Three-dimensional (3-D) – an object that has three dimensions to measure on, such as length, width, and height/depth (Three-dimensional, 2015).

3-D printer – a printer that heats plastic and allows the plastic to be laid flat in layers, creating an object that has an additive formation (layer upon layer) creating an object with width, length, and height (Horejsi, 2014) based on a digital model.

Academic Reading – the “interpretation of a work or performing art given by the person or persons performing it,” (Reading, 2000, p. 11367) “relating to studies that are liberal or classic” (Academic, 2000, p. 7). For example: digital and print books, Web sites, or magazines related to a topic that is being learned.

ANOVA – analysis of variance, a data analysis in which one variable is being compared across two groups to show compared average performance (Salkind, 2004).

Axiology – through a post-positivist view supports that knowing something is “intrinsically valuable” (Aliyu et al., 2014).

Constructivist - supposes that a learner develops knowledge through his or her interactions and experiences with the surrounding world (Ertmer & Newby, 2013).

Curriculum - “basic environmental structure from which teachers are to develop teaching strategies for specific classroom groups” (Beauchamp, 1982).

Curriculum Intervention – a structure of teaching (Beauchamp, 1982; Intervention, 2000) that is used to have an influence on what happens (Intervene, 2015) in the way that teachers specifically teach a specific classroom (Beauchamp, 1982).

Diffusion of Treatment - when subjects in the control group and an experimental group in a study communicate and influence the other group (Creswell, 2013, p. 23)

Digital content creation – “the use of computer technology” (Digital, 2015) to invent or “bring into existence” (Create, 2015) content related to the academic subject being studied. For example, three-dimensional computer models, making websites, blogs, social media postings.

Digital fabrication – “the use of computer technology” (Digital, 2015) to “move through the processes of inventing or manufacturing items” (Fabrication, 2015) that can be printed in either a three-dimensional form, or two-dimensional outline to be made into three-dimensional form, using a two-dimensional or three-dimensional printer

Emergence - well-known elements that, when put together, take on new properties that would not have been possible separately (Cerf, 2012).

Epistemology – “how we know what we know” (Creswell, 2013, p. 23)

Factorial analysis – a complex version of variance analysis used when there is more than one variable being explored (Salkind, 2004).

Hypertext – a linking system that allows a user to navigate between different sources of digital information

Hypermedia – combines multimedia and hypertext to provide an interactive experience as a user navigates through nonlinear paths of digital information (Stansell, 2014).

Interactive Web site – a location on the Internet that provides, or allows, the exchange of information between the user on the computer and the Web site location (Interactive, 2015).

Intervention Curriculum – occurring between two points in time as an extraneous method of learning to alter (Intervention, 2000) the way the courses of study are offered in an educational institution (Curriculum, 2000, p. 340).

Likert Scale – a categorical ordering of unidimensional scaling tasks to see participants differing or similar viewpoints, creating different responses on psychological objects (Dunn-Rankin, Knezek, Wallace, & Zhang, 2012).

Maturation – when participants in a study mature and naturally change with no correlation to the intervention (Creswell, 2013).

Media - a form of mass communication, such as the Internet, newspapers, radio, etc. (Media, 2015) as derived from being a medium, which is a way to communicate (Medium, 2015).

Methodology – “the process of research” (Creswell, 2013, p. 23).

Model Building – the creation of a smaller, physical, three-dimensional representation of an object, person, or structure (Model, 2015) with one’s own hands, such as origami, dioramas, and replications of real-life places.

Multimedia - various forms of media being used in parallel to communicate information (Moos & Marroquin, 2010).

Ontology – “Nature of reality” (Creswell, 2013, p. 23)

Post-positivist – a philosophy or belief that although knowledge about humans cannot always be certain through empirical research, there is still a likely cause and effect relationship that can be supported through the scientific method and numerical means (Creswell, 2013)

Project-based Learning - at its core, an instructional design model that focuses around student interests in real-world problems which lack a single solution and draw from multiple disciplines requiring critical thinking, collaboration, and problem solving for a solution to be proposed (Schwalm & Tylek, 2012); focuses on students physically interacting with real-life, open-ended, and ill-structured problems of the world (Kumar & Natarajan, 2007).

Qualtrics – online software that specializes in enterprise data collection through surveys (Who we are, 2015)

Quick Response (QR) codes - two-dimensional barcodes with a storage capacity of up to 1,000 characters, which can be used to store relevant information, such as images and markers." (Lai, Chang, Wen-Shiane, Fan, & Wu, 2013, p. E58).

RANKO – software program that analyzes variance stable scaling of paired or ranked data (Dunn-Rankin et al., 2012).

Regression – when students have a score that is higher than average to begin an experiment, the chances of improving decrease from the pretest snapshot to the posttest snapshot (Creswell, 2013).

Selection – the extraneous variable where participants in a study participate in the study because they have a predisposition related to the study (Creswell, 2013)

Self-connection – seeing how the qualities and nature that makes a person uniquely who they are (Self, 2015) are related, linked, or associated with (Connection, n. d.) the information being learned, such as how can impact oneself and family.

STEM – Science, Technology, Engineering and Mathematics

Transmedia – a combination of different forms of communication that transcend one medium alone by sending the message across multiple modes

Transmedia books - are hard copy or digital books that utilize hyperlinks, quick response codes, digital designs, and fabrication machines to guide students through a series of problems and activities which they are challenged to solve through electronic or other means (Cohen, Smolkin, & Bull, 2012).

TRICIR – computer program that aids in the analysis of existing circular triads or consistency amongst judges, (Dunn-Rankin et al., 2012) often used in conjunction in with RANKO.

WebQuests – purposeful, directed information seeking from different sources on the Internet

CHAPTER 2

LITERATURE REVIEW

Growing Need

For the last twenty years, the International Association for the Evaluation of Educational Achievement has been administering assessments for academic achievement every four years along with TIMMS to provide an international comparison of academic achievement (U.S. Department of Education, n.d.). The TIMMS was developed out of growing concerns from the 1983 study “A Nation at Risk,” which showed that on nineteen different academic assessments, students in the United States scored last on seven and never in the top two (Williams, et al., 2000). The TIMMS study continues to provide many insight into how various countries or educational systems are scoring higher, lower, or about the same as students in the United States. In addition, the TIMSS charts the general growth of students in fourth and eighth grade over time, with the occasional sampling of twelfth graders. Over 500,000 students across 60 countries have participated (U.S. Department of Education, n. d.). Following each TIMMS sampling is an analysis of the comparison among all the countries that choose to participate. Each time the TIMSS is administered, more countries elect to participate in this international study. A summary of how the United States has done compared to the international average can be found in Table 1. The scores are not scaled across the different years and scaled scores show no statistical difference from 1995 to 2011 (Williams et al., 2009; Provasnik, et al., 2012; U.S. Department of Education, 1995; U.S. Department of Education, 1996; U.S. Department of Education, 2000; U.S. Department of Education, 2003a; U.S. Department of Education, 2003b; Williams, et al., 2002).

Table 1

United States TIMSS Scores Compared to International Average

	4th grade math			8th grade math			4th grade science			8th grade science		
	US	Ave	Diff	US	Ave	Diff	US	Ave	Diff	US	Ave	Diff
1995	476	492	-13	527	500	27	508	483	25	534	527	7
1999	NA*	NA	NA	502	487	85	NA	NA	NA	515	485	30
2003	518	495	23	504	466	38	536	489	47	527	473	54
2007	529	500	29	508	500	8	539	500	39	520	500	20
2011	541	500	41	509	500	9	544	500	44	525	500	25

Notes. TIMSS = Trends in International Mathematics and Science Study, US = United States, Avg = Average of US scores, Diff = Difference between US and international averages
*Some data is marked as NA because the 1999 administration was given to only 8th grade students.

During each successive administration after 1995, the fourth grade students show a steady increase in their average performance. The eight grade students, while still above the international average, do not show the same consistent improvement in averages (see table 1). While as a nation, students are increasing their competiveness in these academic subjects, students show greater gains in fourth grade and drop off by the time they reach eighth grade. Thus, at the elementary levels, students are increasing their scores, though they are being lost again during middle school. There is still more that can be done to preserve our nation’s projected growth in math and science as students grow older. To do this, focus must be given to the middle school years by investigating ways to create change that engages all students in math and science and retains their STEM interest through all of their K-12 experience.

Existing and Future Research

In education, there are several factors that can influence student learning. Many of these influences have been studied and they provide helpful frameworks to consider when creating a positive impact for STEM learning during the middle grade levels from fourth to eighth grade. Researchers are studying many aspects of STEM integration including, but not limited to:

- how to capitalize parents influence on students in regards to STEM topics and classes at school (Ducamp & DeJaegher, 2013)
- how to understand the connection between motivation and student STEM achievement and persistence (Ing, 2013)
- how to use scholarships to get STEM majors into teaching (Liou, Desjardins, & Lawrenz, 2010)
- how to support new STEM teachers as they transfer from college into a teaching role (Schuster, Buckwalter, & Marrs, 2012)
- how to identify appropriate technology for a classroom and also, how to identify suggestions for integrating that technology (Norris & Soloway, 2015)

Research is helping to better identify and support STEM teachers with the technology tools they need to be successful. However, these teachers still need a strong STEM curriculum from which to teach. The literature review and current study focus on developing such a curriculum that facilitates improved student attitudes towards school, enriches perceptions of a STEM major and career, promotes academic achievement, and pinpoints the types of classroom activities that foster these positive changes. The post-positivist research conducted will hopefully help to identify some correlations in the type of middle school curriculum that produces student interest in STEM. The post-positivistic research paradigm will also help develop methods to compensate for the unpredictable nature of the people in the study. The author realizes that while the results of this study may not be applicable to all situations, it can help identify trends in similar situations to gain similar results (Cooper, 1997).

Philosophical Background

John Dewey, in the mid-1800s, supported the philosophy that a person's inquiry, through observing and interacting with the world around them, will enable them to actively develop, manipulate, and test hypotheses to gain knowledge (Field, n.d.). Supporters of Dewey's philosophy still maintain that students should have an education that meets their needs and interests (Noddings, 2012). This is what is commonly referred to in education as student-centered learning: educational experiences that foster the active role of learners to become responsible, accountable, and autonomous in their learning (Lea, Stephenson, & Troy, 2003). Dewey was marked with his desire to, "…inform philosophic reflection with everyday practical experience" (Bernstein, 1992). These ideals of growth based on experience, reflection, and individualization can be taken past theory and made a reality using transmedia experiences that students already live with every day.

Middle school students today have spent their entire lives around technology media (Prensky, 2001). However, as Clark (1983) points out, media itself does not create learning. The focus needs to be on instructional methods and other factors, such as the learner's given task, attributes, and aptitude (Clark, 1983), as learning will occur without media. However, in an opposing viewpoint by Kozma, the way in which media creates an interlinked video environment, can present different symbols of information to help create a mental model (1994b), which is in essence facilitates learning. The debate between Clark and Kozma has continued over many years, spurring many research studies that have developed a standard, or unofficial outline, for the use of media in learning environments. Proponents of Kozma (1991) continues to maintain that some learning will occur regardless of how content is delivered but a media medium helps with the construction of knowledge, which continued to oppose those who agree with Clark’s (1983) position that media alone does not influence learning. Clark (1994) outlined three key components to consider with regards to learning and media: the external learning influences must influence and support internal cognitive processes, the instructional design must be properly linked to theory and application, and the tendency to reinvent the wheel with new technologies must be avoided.

The first component of Clark’s belief—external and internal influences—will be addressed through the instructional methods surrounding the media and will be addressed later in this paper. The second concern—linked instructional design—will be addressed through the methods of data collection and analysis to evaluate not the media medium but rather the research questions themselves through careful correlation of theory and construct validity. The third consideration—not reinventing the wheel in the world of technology—is addressed with the historical development of the media, a transmedia book, used in this research. The historical position for this research project is that books are continuously evolving so the new technology of a transmedia book is, in fact, based on a legacy of using similar tools in education. To this end, to be able to use media effectively, one must have an understanding of the development and current state of media, as well as the framework for which that media will be used, along with the roles of those involved in the educational use of the media. Once this is done, the question that Kozma (1994a) posed can be asked: Will a particular media (in this case, a transmedia book) influence learning?

Learning Theory

Individuals have the ever-increasing challenge of processing all the external outputs of the world and inputting them into their own unique reality, simply known as learning. The way in which learners develop a deeper understanding, through age-appropriate cognitive developmental situations, has been studied in many fields, including the field of psychology by Jean Piaget (Fosnot & Perry, 1996; Ertmer & Newby, 1993). Piaget's developmental learning theory expresses that learning occurs through accommodation and assimilation (Leonard, 2002). As learners experience the world, their cognitive processes accommodate to assimilate the new knowledge. An important part of Piaget's four-stage learning theory is that teachers are to provide developmentally appropriate activities to foster student learning (Noddings, 2012) so that students can be successful in their individual accommodation and assimilation.

The human brain has neuroplasticity that allows the brain to develop with each new experience, shown by research completed in the field of social psychology (Prensky, 2001). Neuroplasticity is the brain's ability to respond, change, and acquire new information based on environmental factors, through the physical modification of the neurons in the brain (Knaepen, Goekint, Heyman, & Meeusen, 2010). The limbic system, in the forebrain, is tied to, "emotion, motivation, memory, and learning…[and] help[s] us adapt our behaviors flexibly in response to our changing environment" (Sternberg & Sternberg, 2011, p.46). What a person experiences will create a change in their thinking patterns (Prensky, 2001), as the brains synapses will be created, reinforced, or destroyed through every new experience (Askenasy, Lehmann, Perry, & Voss, 2013).

Developmentally, middle school students are just starting to be able to move into Piaget's fourth stage, where abstract thinking begins to occur (Aqeel & Awwad, 2013). Students in middle school have theoretically already moved through the previous stages of sensorimotor, preoperational, and concrete operational before moving into the formal operational stage (Noddings, 2012). The first stage of sensorimotor is all about movement and symbols. The second stage—preoperational—focuses on memory and emergent imagination and the third stage—concrete operational—focuses on the logical and systematic thoughts beyond one's self (Huitt & Hummel, 2003). Some people may never reach the last stage of thinking, while others might get to these milestones earlier based on the interplay of nature and nurturing environments (Sternberg & Sternberg, 2011). Students in the concrete operational stage should be encouraged to work together in groups to gain multiple perspectives that will assist in shaping their own experiences and knowledge of reality as they move from the third stage of thinking beyond themselves and into abstract thinking (Leonard, 2002). During this final phase, students begin to develop, design, and test hypotheses for future thinking (Huitt & Hummel, 2003; Aqeel & Awwad, 2013).

Constructivist learning theory supposes that a learner develops knowledge through his or her interactions and experiences with the surrounding world (Ertmer & Newby, 2013). Constructivism outlines set roles for students and teachers in the learning environment. Teachers are to design and guide the learning environment, while the students actively bring personal experiences with them to develop new knowledge and understanding about what they have experienced and will experience in an authentic environment (Jia, 2010; Boghossian, 2006; Ertmer & Newby, 2013). Prolonged exposure to these environments will allow the brain more opportunities to adjust over time to the new information and form connections since the brain does not progress through this process without attention or repetition (Prensky, 2001). Learning environments that use constructivist principles, with technology-enriched curriculum, can show higher levels of understanding and engagement (Fox-Turnbull & Snape, 2011; Cakir, 2008; Shay, 2008). Teachers can outline an environment that blends the learners' potential with frames of reference provided in the instruction (Saettler, 1990) to maximize the learning potential.

Technology Pedagogy

Before designing a technology-rich curriculum, guidance from pedagogy and theory for how that technology is used can help create a cohesive technology-integrated curriculum (Mishra & Koehler, 2006). The underlying pedagogy of the instructors and staff involved will impact the success of any technology in the classroom, despite overcoming other hindrances. The way that content and pedagogy overlap can result in a rich body of knowledge (Shulman, 1987). In teacher preparation courses, most of the focus is along the lines of only specific content knowledge and general teaching pedagogy (Mishra & Koehler, 2006). The way teachers perceive technology can impact their lesson planning in a technology-rich environment (Wadmany & Kliachko, 2014). When technology is added to the existing curriculum development areas of content and pedagogy, the overlap leads to many new types of knowledge that support a successful curriculum and successful teachers (Mishra & Koehler, 2006).

Sometimes the greatest hurdle to change may be the act of accepting the change (Cuban, 2001). A consideration for a change in the fundamental pedagogy of teachers is to move to the assumption that technology is essential for teaching, which will support its effective use and best practice, as it would no longer viewed as an optional item to be abandoned or used as basic lecture support (Ertmer & Ottenbreit-Leftwich, 2010). One way to help bring about this successful interplay of the content, pedagogy, and technology is to foster student-centered constructivist teaching, which encourages the assimilation of new technologies and changing environments (Wadmany & Kliachko, 2014) by its very nature.

Proper instructional design—including theory, pedagogy, and vision, along with active implementation of curriculum reflection—built into a Technological Pedagogical Content Knowledge (TPCK) curriculum supports the critical thinking and situated knowledge that is the end goal of STEM (McKenney & Voogt, 2012). TPCK is outlined by Mishra & Koehler as having:

- being able to represent concepts through technology
- using technology through pedagogically sound ways to show a concept
- ability to understand what concepts may be easy or difficult to learn
- what students already know, epistemology, and how to use the two to add to or modify what students already know (2006)

To help apply TPCK for effective teaching with technology, one must consider the following question in the selection of that technology: What will this technology specifically accomplish and is it the most effective, efficient, and collaboratively encouraging tool that could be used to meet the intended objectives (Marcoux, 2012)? This pedagogical framework, when applied with constructivist theory, will help prepare teachers to handle different types of learning environments where technology is embedded beyond a single subject area (Mishra & Koehler, 2006; Koehler & Mishra, 2005). Instead of trying to make substantial changes all at once that oppose existing beliefs and pedagogy, small incremental changes that directly address areas of weakness in the curriculum should be considered (Burkhardt, 2014). These small interventions, done through a constructivist theory and sound overlapping of content, technology, and pedagogy, have the potential to slowly build a cohesive standalone curriculum. The exposure to these new intervention challenges should last only a couple of weeks to encourage student and teacher attempts, while avoiding overtaxing the teacher in the vulnerable space outside his or her comfort zone (Burkhardt, 2014). For students and teachers to be successful in this transitional time, they need a supporting curriculum that integrates technology with solid theory and pedagogy, while allowing them to think critically about multiple disciplines in a facilitated and developmentally appropriate way (Masek & Yamin, 2010; Kumar & Natarajan, 2007). Pedagogy supporting technology, media, and use of the Internet may play a significant role in providing engaging curriculum.

Curriculum

Curriculum is, in essence, the basic structure by which teachers develop strategies to teach specific groups of students (Beauchamp, 1982). The philosophical backing, learning theory, and pedagogy together develop the curriculum by which teachers will teach. Beauchamp (1982) outlines that all curricula should include two dimensions: curriculum design and curriculum engineering. Curriculum engineering focuses on the curriculum plan, implementation, and the end evaluation. Curriculum design encompasses the choices and selections for what is included in the curriculum and the associated goals. To facilitate the design, it is important to have an institutionally aligned vision—steps for how this vision can be met and a way to evaluate the progress for obtaining the curriculum vision. Beyond that, curriculum design must identify the key structural elements to research and develop for teaching and learning (Clark, 2009). The curriculum engineering provides a feedback system for the implementation to improve in subsequent uses.

The classroom implemented curriculum, should include in its design on-going improvements that address areas of weakness in small incremental steps (Burkhardt, 2014). Curriculum development needs to be collaboratively directed as a joint effort of many people, including teachers and students (Mackenzie & Bebell, 2014). When curriculum and instruction are designed from the views of state standards and teachers only, the following question arises—Do students view the problems they are faced with as real-life problems that they can connect to in a meaningful way (Hernández-Ramos & De La Paz, 2009)? The curriculum should be presented in a way to students that shows the application of knowledge to the world around them so that they may draw the connections between the curriculum and real life themselves.

The plan for curriculum has been shifting since the 1960s to focus more on learners, especially those that would be considered exceptional or gifted in one way or another (Phipps & Evans, 1968). This shift in pedagogy should be reflected in the way a curriculum is set up and implemented. Constructivism pedagogy can be seen in the curriculum in that all students need to be given some guidance, balanced with their ability to self-direct and to solve problems for a solution (Bamberger & Cahill, 2012). The student-centric focus is central to the constructivist model, so it should also be central to the implemented curriculum. As knowledge is defined by a person's relative experiences and reflection of those events (Leonard, 2002; Fosnot & Perry, 1996), the transmedia book has that pedagogical focus. As students communicate and experience, they develop deeper understandings of the world around them. The curriculum in a transmedia form allows for individualized learning and communication through various mediums, all presented in a format that is straightforward for teachers and students.

STEM Curriculum

Teachers tend to create curriculum based on their practical knowledge, content knowledge, and beliefs. In addition, curriculum designers must address the beliefs and goals of outside institutions, including those of national, state, or local education policy (Boschman, McKenney & Voogt, 2014). A tendency exists amongst teachers to view their content as being absolute, making integration of other subjects difficult (Priestley, 2010). The STEM concept itself does not specify a curriculum model or concept but rather a guiding goal (Herschbach, 2011). The goal of STEM education is to expose learners to an interdisciplinary curriculum that integrates more than one academic subject into all the major course activities. STEM moves beyond just the basic disciplinary curriculum of everyday knowledge and transitions students to a reconstructed level of curriculum in which they are able to experience concepts that defy being limited to one subject or another, all while having a solid foundation of academic work underpinning that experience (Applebee, Adler, & Flihan, 2007). Each part of STEM is individually well researched and studied but when each subject is put together the collective behavior and the results are not as predictable as the individual parts. STEM subjects overlap, encouraging students to make interdisciplinary connections (Locke, 2008) in a way that is relevant to real life. By utilizing a series of well planned activities in which all subjects are equally important, it is possible to retain the interdisciplinary STEM blend and real-life application without getting too disconnected from the original independent curriculum objectives. Each of these subjects needs evaluation on its own to ensure that each is epistemologically preserved (Herschbach, 2011); though, STEM itself is an example of an emergence.

Emergence is when well-known elements are put together and take on new properties that would not have been possible separately (Cerf, 2012). Along with the content areas, the critical thinking and collaborative skills that underlie STEM education and career success should be considered (Ejiwale, 2012) since they are a result of the emergence effect. A shift from independent subject curriculum to an integrated series of STEM intervention curriculum activities can help to meet the national goals of fostering a competitive nation, for example, in engineering majors and careers. Focusing the K-12 environment on an extensive study of technology and engineering situations could help students transition into STEM engineering courses in college (Locke, 2008).

A weeklong study by Goonatilake and Bachnak (2012) discovered that even a short intervention using a STEM curriculum can sway students into a positive view for following a STEM course of study and career field. Interventions do not need to precipitate wide sweeping changes, but rather can be something as simple as a single learning activity, a different type of assessment, or a new technology integration (Anderson & Shattuck, 2012). As long as the intervention design takes into account four characteristics for effective intervention, it can be successful: The four characteristics are "…frameworks for learning, the affordances of the chosen instructional tools, domain knowledge presentation, and contextual limitations" (Mingfong, Yam San, & Ek Ming, 2010, p. 470). These interventions should be developed over time through the collaboration of all interested parties to help identify and develop the interventions (Anderson & Shattuck, 2012).

In the design of the curriculum, one must understand the interconnectivity of STEM, foster analytical skills, apply different modes of instruction based on learners' cognitive development, and align content vertically in sequential courses (Locke, 2008). Students must then take what they learn across different courses and intertwine that knowledge to be able to critically think and evaluate potential solutions considering multiple subjects and viewpoints (Lee & Kolodner, 2011). Through the constructivist view, a learners are at the core of creating meaning from new experience, so they must be open to the potential for changing what they previously knew based on new experiences (Ertmer & Newby, 1993). The best way to become open to change is through an experience in which the learner feels safe to explore the learning target; so, having a theoretically backed curriculum for STEM is crucial. For students to feel that level of comfort and security, their teacher (or guide in the process) needs to have a similar level of comfort with STEM experiences. Teachers' exposure to STEM should develop over time (with consideration given to the teachers' comfort level) to be able to handle changes in curriculum (Bamberger & Cahill, 2012). Teachers will need training to adjust to a new curriculum format that encourages idea expression, development of professional relationships, reflective insights, and synthesizes applications to real-life situations (Mackenzie & Bebell, 2014).

Teachers evaluate the practicality of any curriculum (including STEM curriculum), considering the physical or time-based limits of a classroom, how students may potentially respond, and whether the curriculum is actually feasible within these limitations, while still meeting the expectations of all interested parties (Boschman et al., 2014). Curriculum intervention is a subtle and short change that has the potential for success in teacher integration and student learning. The end goal of any intervention in curriculum is preparing the teachers to be guides and also preparing the students to interact in a more self-directed manner. To make this happen, students need to be actively engaged, expanding their own thought processes and connections across the units of instruction. A transmedia book with a set beginning and end adds to the intervention curriculum in a way that allows teachers and students to feel more at ease as they can see the road map for the intervention. The transmedia book is considered an intervention because it can be used independently of other curriculum in the class in a relatively short period of time.

The Center for the Study of Mathematics Curriculum held a workshop discussing *The Future of STEM Curriculum and Instructional Design: A Research and Development Agenda for Learning Designers* (2012), in which the objectives included using current and future technologies to develop STEM curriculum and instructional design. The summary of the workshop included the possibility of books that could be consistently updated, linked to many sources, which encouraged communications across a diverse group of people (Center for the Study of Mathematics, 2012). The expectation to teach a STEM curriculum to a diverse group of students create a demand on instructional designers that they create rich learning opportunities that incorporate many different tools and resources (Center for the Study of Mathematics, 2012).

Instructional Design

Two tactics for instructional design are learning theory and observation (Gagne, 1997). Theoretical underpinnings help instructional designers with the selection of strategies, techniques, and the foundation of the educational experience in a learning environment (Ertmer & Newby, 1993). The constructivist theory aligns with students learning from the interactions they have with their environment, while interpreting and expanding on the ill-structured and authentic tasks they are faced with (Ertmer & Newby, 1993). Ertmer and Newby (1993) outline that the instructional design for a constructivist learning model should include:

- meaningful contexts
- learner control and ability to manipulate information
- content exposure in multiple forms
- problem solving
- transfer of knowledge is the focus of assessment (p. 66)

To develop a system that will facilitate learning based on a constructivist model, it is important to look at all the individual parts, as any one part of the system could hinder the instructional and learning process (Dick, Carey, Carey, 2009). The system, and the individual components, "The instructor, learners, materials, instructional activities, delivery system, and learning and performance environments interact and work with each other to bring about desired student learning outcomes" (Dick, Carey, & Carey, 2009, p. 1). Once all these individual pieces are in place, the second tactic of instructional design comes into use. Observation entails looking at, “what a teacher does in delivering instruction” (Gagne, 1997, p. 11).

Delivery System

A delivery system is how the instructor exposes students to the outlined curriculum in the instructional design (Dick, Carey, Carey, 2009). A delivery system teaching model that aligns with the previously expressed epistemology is the model of project-based learning. Project-based learning focuses on students physically interacting with real-life, open-ended, and ill-structured problems of the world (Kumar & Natarajan, 2007) using whatever tools they have at their disposal. Project-based learning is a teaching model that focuses around student interests in real-world problems that lack a single solution and draw from multiple disciplines requiring critical thinking, collaboration, and problem solving for a solution to be proposed (Schwalm & Tylek, 2012). Project-based learning also provides a framework to keep students engaged as they explore an interest, as opposed to awaiting the teacher to engage or entertain them (Johnson & Delawsky, 2013). At the core, project-based learning encourages student collaboration, and self direction, to complete sequential activities based on authentic tasks to create a final project (Mills, 2009).

Transmedia books can provide a framework for implementing project-based learning. The transmedia book allows students to move through the projects at more of an individualized pace. The individualized pace helps encourage the student to take responsibility for learning (Johnson & Delawsky, 2013). The knowledge gain that occurs through project-based learning engages students who may have difficulty engaging in a more traditional classroom (Schwalm & Tylek, 2012). The use of the Internet is a standard medium for students to research, apply, create, and share in an interdisciplinary way (Cerf, 2012) that transmedia can utilize. The driving questions of curriculum still exist in project-based learning but they are experienced in a manner that supports the transfer of content to new and different situations (Alozie, Eklund, Rogat, & Krajcik, 2010). Shifting from the key curriculum concepts of facts to memorize to questions to explore like professionals in the field, middle school students thrive in a setting where there is the opportunity to collaborate, create, and yet still be independent with their own learning (New York City Department of Education, 2009).

Exposure to STEM curriculum through project-based learning could help students, even if this type of learning experience is introduced later in the curriculum (Gehlhar, Wüller, Lieverscheidt, Fischer, & Schäfer, 2010). Students may be initially unsettled by the differences in the project-based learning approach compared to a traditional classroom with lecture and recitation. A project-based transmedia book is an ideal way to introduce this curriculum to students, as students solve the curriculum problems while gaining STEM knowledge. The project-based learning transmedia STEM intervention blends the necessary components for students to be actively engaged in meaningful technology integration of authentic tasks, making academic connections, socializing to develop knowledge and skills—all happening seamlessly while creating solutions to real world problems.

A transmedia book can provide a a delivery system for STEM curriculum that incorporates technologies and media while having the following characteristics: flexibility to meet the needs of individual students, ease of implementation, incorporation of skills and content that positions students to be successful in a global economy, theoretical and pedagogical backing, and utilization of technology in a way that facilities digital savvy.

Transmedia Framework

The International Reading Association in 2012 argued in their committee summary that students need to be exposed to print and non-print reading, Web-based learning experiences, as well as multiple sources of information. Having this exposure enables students to read and discuss a variety of texts, as well as create their own multimodal products with information from multiple subjects and disciplines (International Reading Association, 2012). Transmedia books harness the potential power of both books and multimedia while still maintaining the tenants of a student-centered learning environment that encourages students to experience continual growth, which is the goal of education. At the National Technology Leadership Conference, the Presidents summary identified one of the top five items identified to transform education was transmedia books (McPherson, 2011); the use of transmedia books meets the Office of Educational Technology's challenge to "… leverage technology to create relevant learning experiences that mirror students' daily lives and the reality of their futures" (U.S. Department of Education, 2010, p. 9). Transmedia books can help meet all the goals of the International Reading Association while also teaching a variety the variety of disciplines in STEM.

Students who engage in transmedia books are engaged enough to persevere through the multidimensional challenges they are faced with (Cohen et al., 2012; Roblyer & Doering, 2006), allowing for greater educational application and attainment. However, there is a delicate balance between the media being used as a critical component of the story and learning event, and the media being used for the sake of using that technology, and ultimately becoming a distraction (Lamb, 2011). Transmedia's use of hypermedia takes advantage of its key strength, which allows multiple ways and sources from which to gain and reflect on information (Roblyer & Doering, 2006), resulting in the cognitive growth of knowledgeable on a particular topic. Students' abilities to choose their learning paths support higher levels of student engagement because they get to think and do, as opposed to just passively following a lesson as outlined by another individual (Killian, 2011).

Since the learner directs their knowledge acquisition, transmedia meets the ideals of Deweyan Education in that it can truly be student-led and centered. Students learn through actually researching, doing, and proposing solutions. Project-based learning supports student engagement in meaningful problem solving of real life situations to develop skills for success that will help them transfer knowledge and express that knowledge (Tseng, Chang, Lou, & Chen, 2011). Transmedia has the potential to blend project-based learning, student-centered learning, and TPCK in way that can encourage a blend of all individual STEM contents.

Development of Intervention Tools

Media Evolution

Transmedia books are a culmination of the historical development of media. The new Oxford dictionary of English defines media as a form of mass communication such as from the Internet, newspapers, radio, and so forth (Media, 2015) as derived from being a medium, which is a way to communicate (Medium, 2015). Multimedia includes various forms of these media being used together to communicate information (Moos & Marroquin, 2010). The Internet originally started as a research network for the Defense Advanced Research Projects Agency in 1969, it further evolved with the alignment of the National Science Foundation in 1985, the World Wide Web and HTML were developed in 1989, and commercial use began in 1992 (Vaughn, 2011). Since then, the Internet has become an ever-expanding network for a variety of media in different forms of text, interactive animations, pictures, diagrams, and videos.

As the Internet grew and developed, the amount of multimedia grew, too. Hypertext was developed as a way to organize and navigate what was quickly becoming an immersive environment (Stansell, 2014). Hypertext is what allows a person to move from one media to another, connecting them at different locations on the Internet (Moos & Marroquin, 2010). The combination of multimedia and hypertext developed into what is known as hypermedia. Hypermedia allows an interactive connection of multimedia through linear and nonlinear design to allow for the easy access of information that the user is trying to find (Stansell, 2014). Hypermedia can even adapt to the user's needs through software that analyzes the patterns in the previously accessed information to provide suggestions for related content (Milosavljevic & Oberlander, 1998; Brusilovsky, 2001). A common example of hypermedia used in everyday life are quick response codes that Lai et al. (2013) define as a barcode that can store up to 1,000 characters in a two-dimensional way that can be scanned by a personal device and accessed. These quick response codes allow a user to quickly navigate to any Web location within a few seconds on their personal digital device and can be embedded in any print or digital medium. The use of technologies, such as these, is creating change in many traditional forms of communication, including in print media and education, as can be collectively seen in a transmedia book.

Electronic Books

One foundational component of education that is undergoing a media change is books. Paper, writing tools, movable type, and books, were all once new technologies that were developed with the purpose of being able to communicate (Knezevich & Eye, 1970). Books have gone through a growth process since illustrated textbooks such as *Orbis Sensualim Pictus* first appeared in 1657 (Cohen et al., 2012) and pop-up books in the early 19th century (Taylor &

Bluemel, 2003) that strive to bring books from 2-D to 3-D. Books are no longer just bound pieces of paper but rather a collection of related content that can be accessed in the form of pages or screens (Lamb, 2011) with multiple dimensions. Today's books can be enhanced with multimedia, hypermedia, and adaptive media, and can go wherever the reader goes via a personal device. These books are reconstructing what it means to read into a broader definition than the original intent of constructing meaning from symbols (Lamb, 2011) and they are also reshaping the concept of text to include more than just written words and images (Larson, 2010).

Educational software in the 1990s used multimedia to enhance the reading experience by incorporating sound effects, music, immediate feedback, and audio tracks of the story that highlighted words as they were read (McMillen, Shanahan, Macphee, & Hester, 1997; Eshet & Chajut, 2007; Doty, Popplewell, & Byers, 2001). An entire genre of these multimedia books—known as Living Books or electronic books—formed within the arena of edutainment (Eshet & Chajut, 2007; Oakley & Jay, 2008). A study by Doty et al. (2001) corroborated the findings of Matthew (1996, 1997) that using these interactive live books on CD-ROM enhanced reading comprehension over reading the same story alone with an adult present to help answer questions. Eshet and Chajut (2007) conducted a study that showed that even students learning a second language learn incidentally, without realizing they were learning. These studies, and many more, support the potential for multiple modes of media to help learners comprehend what they were reading. As these electronic books continued to evolve to be delivered on personal devices or e-readers, studies like Larson (2010) continue to show high student engagement, learning connections, and student control of their own learning.

For every study supporting these multimedia books, there is a study that shows an ineffectual use of these books for learning. One common thread through the studies is that students could be distracted or irritated at having to watch the animations or listen to the audio tracks of the text (Lefever-Davis & Pearman, 2005; De Jong & Bus, 2002; Oakley & Jay, 2008). De Jong and Bus (2002) found that higher-level students would focus on the text of the story, whereas lower-level students would focus on the illustrations. The study results suggested that interactive books are not a successful replacement for a teacher but encouraged the use of multimedia as a supplement to the reading and learning that were occurring in the classroom (De Jong & Bus, 2002). When a study was done by Segal-Drori, Korat, Shamir, and Klein comparing electronic books with adult instruction, printed books with adult instruction, and electronic books by themselves, no real advantage was found using only electronic books. However, electronic books with adult instruction did increase students' concepts about print reading measures (2009). Some researchers, such as Oakley and Jay (2008), proposed that e-books should be used at home with a student's parents in order to supplement reading at school. Their study corroborated the differing views of these electronic books, in that some parents and students loved them, while others still preferred traditional books for reading (Maynard, 2010; Kundart, Momeni-Moghadam, Nguyen, & Hayes, 2012). Studies such as these continue to occur on small populations with varying results. Further research into the best delivery systems for electronic books is still needed to help determine in what situations these electronic books are helpful or not. The transmedia book allows students of varying reading levels to pick what they choose to engage in, while having the choice to avoid what they might find distracting. The end assumption is that the technology impact would vary by student preference and level, corroborating Clark's view that media does not create learning (1983) but the way in which students are supported in harnessing the tool, very well might. Students learn when they are willingly performing meaningful tasks that, "…engage active, constructive, intentional, authentic, and cooperative activities" (Jonassen, Howland, Marra, & Crismond, 2008, p. 2) which should be the criteria for effective technology use in learning (Jonassen, Howland, Marra, & Crismond, 2008).

By the start of 2000s, the National Education Technology Standards and researchers such as Labbo and Reinking (1999), Lefever-Davis and Pearman (2005), and Shamir and Korat (2006) started to support the shift away from just using technology for repetitive drill practice, toward using high-quality media that engaged the learner in a thinking process. To this end, Shamir and Korat developed a guide for educators to critically evaluate CD-ROM stories on the quality of the books they contained in the categories of:

- age appropriateness
- child's ability to control
- clear instructions
- student independence
- process orientation
- technical features (2006)

These evaluation categories should persist in the evaluations of electronic books today, even though the books are no longer contained on a single CD-ROM and the process of evaluation would be more nebulous due to the dynamic and expansive nature of the Internet and multimedia. A way to organize and evaluate, yet leave the potential media and resources under the student control, is to have a set framework in which the students can explore. One way to do this is through a transmedia book.

All electronic books transcend one media format, which is where the concept of transmedia storytelling and books began to emerge. The concept of transmedia storytelling was coined by Henry Jenkins, a digital media theorist (U.S. Department of Education, 2014) who started defining the concept in his blogs and writings in 2003 (2010). Around the same time there were many other terms such as, “Deep Media” and “Cross-media” (Jenkins, 2010), with examples of what we now know as transmedia being developed under these different names. Ultimately, the name and examples of transmedia have the common thread of stories that use multiple delivery methods in an integrated and uniquely coordinated way so that a nonlinear story unfolds for a reader (Jenkins, 2007).

Transmedia storytelling can be conveyed through various means including books, games, and branding (Jenkins, 2010). In fact, it is difficult to identify the first true example of transmedia storytelling, as books have been turned into movies, movies into games and theme parks, and music into animation. The focus here is the concept of transmedia stories through transmedia books; however, Jenkins has written books and articles that include the scope of other types of transmedia and the history of transmedia development outside of storybooks.

Transmedia Books

Research suggests that storytelling as a way of learning can be used in interdisciplinary fields (Sadik, 2008). A transmedia book, or series of transmedia books, could be used as a curriculum intervention to help prepare students and teachers for a larger shift towards more comprehensive STEM curriculum. Transmedia books provide a way for students’ to interact with a series of problems and activities that they are challenged to solve through electronic or other means (Cohen et al., 2012). These books are often nonlinear in nature because of the necessary participation of the reader (Lamb, 2011). Jenkins (2010) identified that a powerful aspect of transmedia is its ability to show different perspectives and shift the readers’ thoughts and feelings as a result. The ability to shift the reader’s perspective makes transmedia stories an ideal way to help students learn, as they “possesses the power to motivate, persuade, entertain, and educate” (Fleming, 2013, p. 371). These stories make the content more tangible and self-directed for students (Parker & McDonald, 2014).

From 2-D to 3-D

The uses of hypermedia tools embedded in the transmedia book allow students to explore and design knowledge and solutions within a community (ChanLin, 2008). The fluid movement across dynamic sources of media has created a Transmedia Learning World (Fleming, 2013) that allows learners to harness the power of technology to take charge of their own learning. Stories can now become even more influential by inspiring ideas that can leave 2-D and become 3-D through printing processes and digital fabrication. Digital fabrication allows students to digitally create objects that can then be transformed into a physical, non-digital form (Kjellstrom, Tillman, Cohen, & Ducamp, 2012). Software exists that can use various types of fabricators to create 2-D or 3-D objects through different types of printing devices. The software and printers are becoming more affordable, allowing people access to conceive, design, and create objects whenever they have a want or need (Gershenfeld, 2005). In the realm of education, the process of this type of fabrication necessitates a “transdisciplinary creativity, by allowing students to instantiate mathematical, artistic, and scientific ideas in an applied manner” (Smith et al., 2014, p. 2). The different subjects in STEM culminate in the interplay of creating an object through 2-D and 3-D fabrication, giving students the chance to use science, math, and technology to traverse an engineering process in the creation of what they can mentally conceive (Berry et al., 2010). Fabrication on this level allows students to have greater access to materials to work with and change the way hands-on projects can be done (Eisenberg, 2011). Students can read about a problem in a story, imagine a solution for that problem, and actually make that solution a reality through current technology media.

Before including digital fabrication in STEM curriculum, consideration needs to be given for the technology availability gap in the educational setting. Some students may use their own technology devices so there could be a host of different digital devices involved and there will inevitably be differing levels of technology literacy (Marcoux, 2012). A digital divide exists, that is, the separation between people who have reliable access to new technologies and those who do not (U.S. Department of Commerce, 1999). The gap that exists has been an issue that the United States National Telecommunications and Information Administration has been trying to close since the late 1980s (National Telecommunications and Information Administration, 1998). The digital divide definition has expanded from the mere physical infrastructure to now include motivation to know and use technology in an appropriate and meaningful way, as seen in a five-year study by Van Dijk that ended in 2006. The consideration of the digital divide should help to not limit students' access to the use of new or old technologies but rather to identify that some students may need additional help in media literacy. Three literacies were outlined by Koltay in 2011 and include:

- Media literacy – the ability to access and critically evaluate different types of media, including print and electronic, in an autonomous manner to become better informed

- Information literacy – the ability of a person to access appropriate and accurate information in order to make informed decisions about their well-being through megacognitive thought and critical evaluation of a variety of conflicting sources

- Digital literacy – the ability to navigate digital searches, such as through hypertext on the Internet, in order to develop one's own knowledge from sites that have been critically evaluated for their reliability and accurateness

It is also important not to neglect the goal of helping students become more literate. A transmedia book series could discreetly have reading levels, by changing the QR code links; thus, to a casual observer, the series seems to have the same content and projects. In reality, the series could be differentiated to allow the student to be successful without the student feeling singled out by having a different curriculum. As students' progress through the book, their technology skills, content knowledge, and problem solving will all develop through their interactions and creation of products within their learning community (ChanLin, 2008). The story, multiple modes of media, and peer interactions help learning to transfer beyond a single setting and session. Thus, the learning is considered successful when it creates a measurable and sustained change in behavior, such as, "...physical and overt, intellectual, altitudinal, or a combination" (Raybourn, 2014, p. 437). As the story progresses, students add to their knowledge, technology integration, and collaborative reflection in increasingly difficult challenges that must be constructed and developed through multiple forms (Stansell et al., 2015). The book can then lead the participants though an interdisciplinary mesh of curriculum and media-related activities. In addition to the possibility of using discreet differences in the actual books studied, the information and use of technology can be scaffolded in the activities, as not all students will have the same background on how to use the different media types in the transmedia book (Marcoux, 2012). The constructivist theory supporting the instruction becomes important here, in that students can help collaborate in the challenges, learning both the curriculum and technology from each other, helping to close any digital divides in the learning environment.

Transmedia books are a way to facilitate specific curriculum interventions in a nonthreatening and manageable way by a teacher. Teachers using technology with students need to have a strong understanding of the potential educational uses and roles of that medium (Sadik, 2008). Technology has different levels of use, as defined by Lim and Tay (2003) which are: informative tools, situating tools, communicative tools, and constructive tools. The use of a transmedia blends all four tools into one. The book as a delivery method for a STEM curriculum intervention helps to inform and situate students in developing literacy and critical thinking in a STEM field while merging appropriate pedagogical models with technology and Internet resources that are age appropriate. Students then take their developing knowledge to use with other technologies to communicate and construct solutions for their particular problem situation.

Transmedia Examples

Transmedia novels can be in print or electronic format. *Inanimate Alice* (2015) is an electronic storybook that takes the reader through a variety of different media puzzles in a nonlinear format in order to progress through the story chapters (Fleming, 2013). The story can be followed in English, French, German, Italian, or Spanish. Students select their preferred language to follow along. The digital novel, *Inanimate Alice*, was created by a team of people but foremost by an "award-winning novelist," a "pioneering digital artist," and a "series producer" (2015). The team members each brought a different component of media to the project and worked with other experts to exemplify the idea of transmedia storytelling and capitalize on the unique affordances of each media. The story is housed on the Internet at http://www.inanimatealice.com/ and has received awards, including one from the American Association of School Librarians (Fleming, 2013; Pullinger, Havard, & Hundley, 2013), even though it is not a hard-copy printed book in a library.

Specific Transmedia Example

Engineers Needed: Help Tamika Save the Farm, a printed transmedia book that was created under a National Science Foundation grant as STEM curriculum, provides a framework for approximately 50 minutes per day, over ten days of STEM activities (Quintanilla, Stansell, Tyler-Wood, & Zimmerman, 2013). Each chapter presents a collaborative constructivist project-based learning experience that applies to real-world situations. The book tells a narrative that speaks to the reader, encouraging them to be part of an engineering team that must help to save a farm, while embedding math, science, and technology skills to accomplish increasingly more difficult engineering problems. The act of reading through the book and completing the challenges engages students in a STEM curriculum. The engagement in the projects may potentially increase interest in an engineering or STEM career path (Stansell et al., 2015) as students see the real-life value in understanding math and science. The book's creation was made possible by having a diverse team that could each speak to a different aspect of the media that was being developed (Stansell et al., 2015).

The diversity of transmedia development teams—their knowledge of their subject areas and their collaborative effort—is what makes such a project successful. It is difficult to say which aspects of a transmedia story will be better received. Each media has the potential to add something unique and special to the experience, as long as it is added for the purpose of STEM interest and problem solving. The purpose of inclusion should be well thought out and follow what has been outlined as an area of caution by the long-standing debate between Kozma and Clark.

Transmedia Curriculum Development

Beauchamp outlined that curriculum should include

> - a statement of intention for use of the document as a guiding force for planning instructional strategies,
>
> - statements outlining the goals for the school(s) for which the curriculum was designed,
>
> - a body of culture content that has the potential for the realization of the goals, and
>
> - a statement of an evaluation scheme for determining the worth and the effectiveness of the curriculum and the curriculum system (1982, p. 25).

The transmedia curriculum designed for this study follows the paradigm of constructivist learning through the instructional strategy of project-based learning. The implementation of this paradigm is proposed to create change in the middle school classroom to encourage more STEM activities through the use of technology in a way that can pedagogically bring about change to those involved. Each chapter in the transmedia book, *Engineers Needed: Help Tamika Save the Farm!*, was designed to engage diverse learners in this paradigm through the selection of different media, in hopes of engaging learners and teachers to change the pedagogical views of STEM and the use of technology. To that end, this study hopes to address the fourth curriculum requirement: evaluating change in student perceptions and academic achievement. If a correlation arises, then the evaluation statement can help adapt the vision of future curriculum to utilize preferred learning activities. The curriculum of the transmedia book used in this study spans only a few weeks, allowing it to be used as an intervention curriculum, separate from the other curriculums that may already be, or will be, taught in the same classroom.

Transmedia Chapter Units

In the transmedia book, *Engineers Needed: Help Tamika Save the Farm!*, each chapter serves as a different project unit. The chapters build in project difficulty, as well as diversifying the necessary media. At the beginning of the book, there are helpful tips and suggested resources for anyone using the book, who may be new to project-based learning, for what items can potentially be used in a solution. Throughout the book, vocabulary words are underlined and linked to an online vocabulary practice source called Quizlet. Readers can choose to practice those words using Quizlet, where there is a variety of online interactive methods to help students learn the vocabulary words. The book also uses QR codes to allow students quick access to other resources and references.

The first chapter has QR links to an online website maintained by the Environmental Protection Agency that guides students through making numerical observations that can be taken and plugged into the website to find their at home water use. This activity supports the requirement in science to observe and record data, while also mathematically computing the results. The website shows the basic calculations, but does the math for the user to focus on the application that math has. In the proceeding chapter, students will do a similar exercise with the amount of electricity they use. An extension could be to have the students do the original math, and then have them check with the online websites. Using this extension depends on the math experience and comfort levels of the students. The book can provide a framework for activities that the students and teachers can collaboratively modify to fit the needs of their classroom.

The second chapter moves the reader into a challenge where they create an origami cup that can hold water. After students experience success with folding paper, they can optionally create a 2-D digital form that they print with a 2-D fabricator. Students must begin to visualize water storage devices in a way other than a traditional cup or mug, as they create a 2-D version that will be folded into a 3-D model. Students begin to think about a type of farm in this chapter, but are still focusing on methods for water capture and collection. In the next chapter the reader is taken through a history lesson for historical methods of water capture and distribution, to further see possibilities for irrigation engineering for the farm type they began to choose in the last chapter. To help with the knowledge building, students perform a Web Quest in the hopes that they not only gain background knowledge, but also try to apply what they are learning to improve their original designs and thoughts.

In Chapters 4 and 5, after having developed a base understanding of water collection and water cycle from previous chapters, students are given a real life problem of dealing with simulated pesticides and pollution. Students build a model for a farm of their choice, and then they are challenged to test their solution to the water collection and treating by collecting and filtering water from the model. In this challenge, they can use everyday items, or make a 3-D fabricated filtration system for their farm. The remaining chapters focus on making a water desalination experiment, making a presentation on future farming practices, and growing their own garden of their sample crop. While each chapter is different, the activities can be summarized into the following types:

- Academic Reading – The “interpretation of a work or performing art given by the person or persons performing it” (Reading, 2000, p. 11367) “relating to studies that are liberal or classic” (Academic, 2000, p. 7). For example: digital and print books, websites, magazines related to a topic that is being learned.

- Digital content creation – “the use of computer technology” (Digital, 2015 to invent or “bring into existence” (Create, 2015) related to the academic subject being studied. For example, three-dimensional computer models, making websites, blogs, social media postings.

- Digital fabrication – "the use of computer technology" (Digital, 2015) to move through the processes of inventing or manufacturing items (Fabrication, 2015) that can be printed in either a three-dimensional form, or two-dimensional outline to be made into three-dimensional using a two-dimensional or three-dimensional printer.

- Interactive Websites – a location on the internet that provides, or allows, the exchange on information between the user on the computer and the website location (Interactive, 2015). For example: online games, online quizzes like Kahoot, vocabulary practices like Quizlet

- Model Building – the creation of a smaller, physical, three-dimensional representation of an object, person, or structure (Model, 2015) with one's own hands such as origami, dioramas, and replication of real life places.

- Self-connection – seeing how the qualities and nature that makes a person uniquely who they are (Self, 2015) is related, linked, or associated with (Connection, 2015) the information being learned such as how things can impact oneself and family.

- WebQuests – seeking information from different sources on the internet

Future of Transmedia

Educational transmedia books are being offered for sale by major publishing companies such as LeapFrog (LeapFrog, 2014) and at no cost online, from organizations like MakeToLearn.org (Cohen et al., 2012) and inanimatealice.com (Fleming, 2013). With more transmedia resources encouraging students to jump between media and reference materials, it will become more important than ever for learners to be able to critically evaluate what they are reading, using, and applying in order to know which information is accurate and viable, versus which information is erroneous and purposefully misleading (Lamb, 2011). The best way to develop this skill is by critical reflection of trial and error through reading, watching, and listening to a variety of information that is reinforced by a more knowledgeable person. In the not so distant future, computer systems will be programmed in a way that combines hypermedia and artificial intelligence in a way that can assess student learning and act as a cognitive guide to learning new educational objectives (Roblyer & Doering, 2006) in a way that would mirror the student and teacher relationship on a more personal level but for now, a transmedia book offers a potential portal into that realm.

In the future, a transmedia story could adapt and guide students to develop content mastery. Research is needed to understand and assess the qualities that will allow learners to learn with the media of a transmedia book so future technologists can build the software and curriculum systems and programs to properly mesh the media and design for learning to occur. A project-based STEM transmedia book used with middle school students can help lend insight into this form of curriculum intervention while also putting the nation on a path to being more globally competitive in the future.

CHAPTER 3

METHODS

Ologies

Epistemology

A post-positivist approach was taken with the collection and analysis of the quantitative data. While empirical evidence through the scientific method of manipulated and controlled variables was use, the study recognizes that the analysis cannot guarantee an absolute understanding as the subjects being studied are humans naturally prone to complexity (Creswell, 2013). However, it may be possible to identify some effects of using a transmedia intervention book in a middle school classroom. The quantitative instruments helped in the observation and analysis of any correlations of the STEM intervention on the research in question. While the axiology of the post-positivist view supports that knowing the results of the intervention is its own reward (Aliyu et al., 2014), the hope is for this experimental study to be a starting place for creating change in education to incorporate more STEM project-based activities.

Methodology

In education, many studies are scrutinized under the extent to which they have met the "gold standard" for educational research methodology. The gold standard is defined as, "Well-designed and implemented randomized controlled trials…" (United States Department of Education, 2003, p. 1). In an effort to meet this standard, different classes of seventh graders at the same school were classified as either an intervention class, a semi-intervention class, or a control class. The intervention class experienced the full transmedia intervention. The semi-intervention class experienced the transmedia story without the optional activities using 2-D and 3-D fabrication. A third class, the control group, experienced their regular STEM elective curriculum. The standard STEM curriculum involved learning about different types of engineering through doing research and completing a projects showcasing different types of engineering. All classes that participated in the experiment had the students in that single class performing the same learning activities to prevent cross contamination of groups. All students participated in the unit over the course of the year; however, only the first phase in the counter-balanced method was evaluated. As elective classes are already established by an interest and border on simply a comparison group, a static group pretest-posttest design (Fraenkel et al., 1993, p. 270) was performed with each group to help reduce threats to internal reliability for extraneous variables, such as maturation, selection, regression, and diffusion of treatment (Creswell, 2013).

To introduce the study to the students, the teacher read a provided script to overview the study and then passed out a parent and student permission form that gave assent and consent for student data to be collected. Information which overviewed the study was also posted on the participating teachers' websites to facilitate conversation with students and parents. The application "Remind," already established as a communication tool with parents and students in the implementation school district, was also used to send a notice to families currently using the application whose children were in the classes involved in the study. In addition, the participating schools hosted a parent night during the first week of school and this forum was also used to provide information on the study to parents and students. The data for students who returned signed permission forms in the two intervention classes was analyzed; the data for those who did not choose to participate were not included in the study instruments. However, students for which data was not collected did perform the same activities as their classmates to prevent being isolated or singled out in their class for lack of participation in the study.

Resources

Participants

The target population was all seventh grade middle school students in a single middle school. However, the accessible population included 69 seventh-grade students at a single middle school near Austin, TX. The school has historical demographics of between 500–800 students across its three grade levels. The ethnicity breakdown of the school historically has been around 69% White, 17% Hispanic, 5% African American, 4% Asian, with around 1% Indian and two or more ethnicities. At the school for the study, it was not possible to have a random sampling of subjects due to the existing scheduling of intact elective classes, so a nonrandom convenience sampling was used from the three existing seventh-grade STEM elective classes. A limitation in this sampling is the difficulty in generalization, unless common trends strongly occur across all groups (Fraenkel et al., 1993) or similar trends exist in future situations. Basic demographics included in the pretest instruments helped to gain insight into the differences and similarities across the groups, as well as to help with similar generalizable situations.

Materials

All students completed the pretest, posttest, and psychometric surveys, which included some demographic questions through the schools internet. The instruments were primarily combined into a single online survey, broken into sections for each instrument, in Qualtrics. All students needed Internet access, a computer or personal device in class, and a shared copy of the transmedia book. The school already provided a class set of Wi-Fi enabled computers that could access the school Internet, which provided the necessary access. The provided computers or personal devices were used to gain access to the electronic resources and references from the transmedia STEM book in the process of completing their project. The intervention class also needed access to a 3-D fabricator, along with the same miscellaneous supplies the semi-intervention group needed that are listed in the book. The STEM elective class already had access to a Replicator 2X 3-D printer for project use.

Instruments

Each of the research questions was evaluated with a different instrument. Each instrument was analyzed for differences across groups, as well demographic information obtained from each group. All instruments combined helped to address the changes that occurred from the start to end of the intervention. Each question had an identifying number that was utilized during the data analysis phase. All data presented is a summarization of the question or construct being measured by the instrument.

STEM Semantics Survey and Career Interest Questionnaires

The STEM Semantics Survey and Career Interest Questionnaire were used to address the research questions: (a) Do students' perceptions of STEM change after experiencing a STEM intervention curriculum? and (b) Do students have a change in their STEM interest as a career? The instruments were adapted from previously existing instruments as part of a grant funded by the National Science Foundation for Innovative Experiences for Students and Teachers to assess perceptions of STEM in the Middle Schoolers Out to Save the World project (Tyler-Wood, Knezek, & Christensen, 2010). These instruments were developed and evaluated through successive years of the project implementation and continue to be used in other studies. During an "…exploratory factor analysis (principal components extraction, varimax rotation, suppressed display of loadings < .5)" (Tyler-Wood, et al., 2010, p. 12), both instruments grouped components based on the hypothesized and intended concepts. The sample size was not large enough for a confirmatory factor analysis. The small number of participants in this study is also a limitation.

The Career Instrument Questionnaire consists of 12 Likert-style questions that are split into three parts. The instrument was used twice to assess broad interest in science careers and a second version for math career interest. The three main constructs evaluated are “perception of supportive environment for pursuing a career in science, interest in pursuing educational opportunities that would lead to a career in science, and perceived importance of a career in science” (Tyler-Wood, et al., 2010, p. 8). The instrument was originally designed with a pure science focus but it can be modified to fit any STEM subject (Tyler-Wood, et al., 2010). During the instrument’s initial development, it showed a Cronbach’s alpha ranging from .78-.94 (Tyler-Wood, et al., 2010), showing a “respectable” to “excellent” reliability (DeVellis, 1991). The original science version of the Career Instrument Questionnaire was used, as well as a math version to help gain insight into both subjects, because a previous pilot study showed there was a difference in the perception of math and science with the STEM Semantics Survey instrument.

The STEM Semantics Survey contains 25 Likert-scale questions that are split into the five sections of science, math, engineering, technology, and a career in STEM. Participants of the survey included both students and teachers (Tyler-Wood, et al., 2010), though this research is primarily focused on the application with students. During the instruments’ development, it showed a Cronbach’s alpha in the range .84-.93, showing that it had “very good” to “excellent” reliability (Tyler-Wood, et al., 2010).

School Attitude Assessment Survey–Revised

The School Attitude Assessment Survey-Revised was used, with the permission from the one of the instrument developers, Dr. Betsy McCoach, to address the following question: Do students have a different attitude towards school after experiencing the STEM intervention curriculum? The instrument was originally developed as a large-scale quantitative measure of secondary students' underachievement based on the characteristics of "…attitudes toward school, attitudes toward teachers, goal-valuation, motivation, and general academic self-perceptions…" (McCoach & Siegel, 2003). Students who could do better in school, but do not, tend to do so because of the characteristics that this instrument was developed to evaluate. The factors studied using the School Assessment Survey-Revised influence the other factors being analyzed in this current study—students may not be motivated, may have a negative attitude towards the school or teacher, or may have a fear of failing, which may correlate to low academic achievement or low STEM interest as a goal.

The School Attitude Assessment Survey-Revised went through implementations and revisions before becoming the current 35 question 7-point Likert scale items. Part of the revision process was the removal of previous question items that correlated in more than one of the constructs that the instrument hoped to evaluate (McCoach & Siegle, 2003). This process was determined by, "…several common fit indices including chi-square ($\chi2$), the ratio of chi-square to degrees of freedom ($\chi2/df$), RMSEA [Root Mean Square Error of Approximation], CFI [Comparative Fit Index], TLI [Tucker Lewis Index], (also known as the Bentler-Bonett Non-Normed Fit Index), and SRMR [Standardized Root Mean Square Residual]" (McCoach & Siegle, 2003, p. 7). The instrument developers added some new questions, reworded questions, and kept some of the original questions, the final instrument that was used showed:

> All factor pattern coefficients were significantly different from zero and in the proper direction, and all factor correlations were significantly different from zero. The final model exhibited reasonable fit, $\chi2(550) = 1{,}581.7$, CFI = .911, TLI = .918, RMSEA =.059, SRMR = .057. The final instrument contained 8 questions on the Academic Self-Perceptions factor, 7 questions on the Attitudes Toward Teachers factor, 5 questions on

> the Attitudes Toward School factor, 6 questions on the Goal Valuation factor, and 10 questions on the Motivation/Self-Regulation factor (McCoach & Siegle, 2003, p. 9).

Independent reviews of the factorial analysis from use of the instrument further support that the instrument can measure the intended factors, with additional criterion-related validity and convergent validity (Suldo, Shaffer, & Shaunessy, 2007).

Activity Rankings

A RANKO and TRICIR computer software analysis of activity type ordering was used to address the question: What kind of activities did students value the most that can be used to further develop STEM intervention curriculum? RANKO is a computer software program that analyzes variance stable scaling of paired or ranked data (Dunn-Rankin et al., 2012). TRICIR is a computer program that aids in the analysis of existing circular triads or consistency amongst the respondents (Dunn-Rankin et al., 2012), often used in conjunction with RANKO to help see where respondents are inconsistent with their preferences. The activity pairings went through some changes in the definition and examples provided for each activity type to communicate an accurate understanding of the choices provided prior to the study. The goal of this instrument is to allow the students to make an ordering choice based on their actual preference for the presented activities. The ordering of the object pairs for the activities is done in accordance with the balanced orders for pair comparisons (Dunn-Rankin et al., 2012, p. 212). The activity preference instrument is still under development and was not a primary source of information. Instead, it was used to provide some additional insight into the future modeling of STEM curriculum as the instrument develops.

Academic Measures

To address the research question of what kind of academic achievement/gains can be seen from implementing a STEM unit. Previously released questions from the TIMMS were utilized. Each of the released questions from previous TIMMS includes a marker for the average score on that question for students in the United States, as well as the overall average for all countries. All released math and science TIMSS questions for eighth-grade, including some from fourth-grade for a benchmark, were taken into consideration. The students in the study were seventh-graders, so it was expected that the students may not score as well as the international or national averages for these questions. However, given that the questions were a year advanced from the students, it was expected to still provide a benchmark.

As this study is quantitative in nature, all open-ended questions were removed from consideration as the rubric grading has a qualitative necessity. After this elimination process, the remaining TIMSS math and science questions were selected based on specific content related to the transmedia book or for general thinking processes in science and math that are not content specific. These questions were then paired based on content, cognitive process, and relative international average for the percentage answering correctly. Questions that were paired were then split into two groups with one of each pair being used in either the pretest or posttest to help create a relative comparison of difficulty and achievement on the questions before and after the implementation period. Paired questions from the released fourth-grade TIMSS were placed at the end of the academic sections in both math and science. This was done to help indicate if students were able to answer easier questions at the end of the instruments in order to help identify subject burnout from the instruments. To assist in avoiding student fatigue, dropouts, and random marking for the surveys, the academic measure portion was kept short like the other instruments, with only the highest correlated questions in math and science being used in the final version of the instrument. The instrument has potential use for other STEM teachers as it imposes less on class time, teacher time grading, has correct or incorrect answers, and relatively inexpensive like other STEM assessment instruments being developed (Harwell, 2015).

The Intervention

The transmedia book in this study was written as intervention book with unique projects to problem-solve in the field of agricultural engineering. The final unit was written to be done with an optional capstone project of developing a solution through software that to went from digital creation to being physically fabricated with a 3-D printer. Given that students learn through the research and development of creating STEM-based project solutions, the 3-D printer is an applicable setting for the STEM, TPCK, and PBL blend to occur. Students were able to physically make a product based on the meaningful application of knowledge that they had constructed by communicating with their peers and interacting with various resources, including questioning their current understanding of a problem. An experimental design included three different groups, the control, the semi-intervention that did not include the 2-D and 3-D printing fabrication, and the group that included all these devices, helped to shed light on where the greatest gains in academic success, STEM perceptions, and school attitude occured.

Procedure Plan

The following procedures were followed. A note was sent home accompanying parental permission and student consent forms. Information was posted that overviewed of the study on the school website. A message through Remind was sent to notify parents of the study. Students who returned both completed forms were assigned a pseudonym to protect student identities while analyzing the data for any trends. To help with pretest and posttest alignment and accurate record keeping, the Qualtrics Internet survey software platform asked for students' school identification number that was then changed into their assigned pseudonym. The pseudonyms were not shared with any of the teachers or students involved in the study. Any questions regarding the study were directed to the lead researcher to address directly. The teacher followed instructions on how to introduce and facilitate the unit, along with the schedule of the type of intervention, experimental, semiexperimental, or control, each class participated during the intervention phase. The class designation for the intervention type was determined based on the number of students participating in each class to try to create equal sample sizes for each experimental and control group. All pretest and posttests of students who consented to the study were given to the researcher for data correlation purposes.

Implementation Timeline

The first day of the academic school year for the implementation school was August 24, 2015. Information about the study had been posted on the classroom teachers' website before classes started. On the first day of school, there was discussion about the study with the students who were involved and the approved IRB forms were sent home. Four days later, a follow-up e-mail with information was sent home to parents before the school's open house, where parents were further informed about the study and were able to ask questions. The following week, the pretests were administered. The pretest administration spanned two days for students to be able to complete them. Additional time was needed for some students to accommodate them when Qualtrics "froze" part of the way through their responses. It was eventually determined that, when the district increased security measures over the summer, the school web filters limited the access of some students to Qualtrics because of the students age, actually stopping the survey part way through. This issue was resolved quickly upon discovery and all pretests were completed by the end of September 4th, including four new students that came in that week who brought permission forms.

The three 7th grade classes involved in this study were randomly selected to be either a control group, full experimental group, a semiexperimental group that used the book but did not do the optional book projects with the 2-D cutter and 3-D printer. The final group was a control group that proceeded with the normal STEM curriculum of the classroom, focusing on research projects and self-selected presentations of STEM topics. As the transmedia book consisted of group based STEM projects, all three classes were allowed to choose their groups of between 3-5 students for their group based projects. Students in all classes were allowed to change groups if issues arose that prevented them from being able to complete the projects. Only one group in the semiexperimental group split into two separate groups. After the split, both groups were able to continue with the projects more efficiently. While all groups had the option to choose new groups in their class period during the course of the study, no other groups changed.

Several computer issues arose because the school district was changing from MAC computers to PCs at the middle school level. During this process, websites became blocked that were not previously blocked because of website filtering issues. Some projects from the book were done out of sequence to accommodate for routine Internet technology processes to be accomplished that were a part of the computer system change. These processes included approval and installation of certain websites and software plugins.

At the end of September, all experimental classes were close to completion of all projects in the transmedia book. The percentage of students who had completed the various book chapter projects was tracked daily to make sure that students in these groups did not experience additional classroom activities that might deviate from the book and cause unequal groups. The groups finished the book projects in the time period of September 28-30. The issues with the pretest technology glitches had been resolved and tested so the post data collection was able to occur over only two days, October 1st and October 2nd.

The implementation school had different bell schedules on Tuesday/Thursday (T/Th) and Monday/Wednesday/Friday (MWF). On T/Th, there were 48-minute class periods, while on MWF, classes were 52-minutes long. In addition, there was a pep rally and assembly, which limited the class periods to 45 minutes in length on two Fridays. There was one holiday without school and, also, an early- release day, where students were in class for approximately 30-minutes a class periods. The total class time spent from the beginning of the pretest administration to the completion of the posttests was between 19 and 20 hours. During this time, the two experimental groups were able to complete all book projects, including the optional 2-D cutter and 3-D printing projects. The semiexperimental group was the first group to begin finishing but the experimental group finished within two days after the semi-experimental. The control group worked on the regular classroom STEM projects and was at the conclusion of one of their projects at the same time.

CHAPTER 4

RESULTS

Demographics

A total of 69 participants were divided into three comparative groups. All students were 7th graders and 38 of the students were male. The demographics question asking why students joined the STEM elective showed that fifty-four of the students self-reported that they joined by choice, two because of the lack of other elective choices, one was placed without choosing, and three because their parents made the choice for them.

Students self-selected their ethnic background. The self-reported demographics included 46 white non-Hispanic students, seven Hispanic students, and seven chose “other.” Four students selected Asian; two selected Indian, one selected African-American, and two students selected the choice of multi-ethnicities. Forty-five of the students interact with a family member who is involved with STEM, while 13 students said they do not, and another 11 students were uncertain if they do or not. Fifty-five of the students had not been previously involved with STEM, 13 students were new to the STEM elective class but had had other STEM exposure. The breakdown of the group’s demographics can be seen in Table 1.

The experimental group received the intervention STEM curriculum that consisted of the transmedia book and the use of the 2-D cutter and 3-D printer. The experimental group was comprised of 19 in students in seventh grade who had not previously taken the STEM elective class. The second group of 22 students, the semiexperimental group, experienced the transmedia STEM curriculum treatment without the use of the 2-D cutter and 3-D printer. The control group consisted of 28 students. The students in the control group did not experience the transmedia book, the 2-D cutter, or the 3-D printer. Instead, their group was involved in the standard STEM curriculum for this elective class.

Table 2

Demographics of 7th Grade Participants by Section

Variable	Experimental	Semi-experimental	Control
Number of students	19	22	28
Gender			
Male	11	16	11
Female	8	6	17
Elective selection reason			
Requested elective	18	22	24
Lack of other options	0	0	2
Placed	0	0	1
Parents	2	0	1
Racial and ethnic background			
White-non-Hispanic	12	12	22
Hispanic	1	3	3
Black	0	0	1
Asian	1	1	2
Indian	0	2	0
Two or more	1	1	0
Other	4	3	0
Family members in STEM			
Yes	12	14	19
No	2	7	4
Unsure	5	1	5
STEM experience			
First year	12	17	26
Other STEM experience	7	4	2

Activity Ranking

The activity rankings included seven activities to be compared. These were Academic Reading, Interctive Websites, WebQuests, Model Building, Digital Content Creation, Self-Connection, and Digital Fabrication. The sufficient number of judges needed for a .10 Alpha level was 68. The sample size of the study included 69 students across all three groups. Given the small individual group sizes, it was not possible to identify differences amongst the individual groups. The Kendall's coefficient of concordance for the pretest was .2446, and .3149 for the posttest. During the pretest students were less aligned on their choices then they were on the posttest. The difference in student selection can be seen through the overall decrease in the number of circular triads across the groups. The activity rankings as a whole contained circular triads across significant groupings of the participants when analyzed through circular statistics.

Table 3

Report on Circular Triads Across the Groups on the Activity Ranking Instrument

	Pretest			Posttest		
	Circular Triads Present	Percent of Judges with Circularity	Kendall's Coefficient of Concordance	Circular Triads	Percent of Judges with Circularity	Kendall's Coefficient of Concordance
Group						
Experimental	54	63%	.2088	25	53%	.2863
Semiexperimental	22	41%	.374 9	29	41%	.5111
Control	51	77%	.2470	35	46%	.2596

The circular triads did decrease for some of the judges, as well as lower percentages of judges with circular triads from pretest to posttest (see Table 3). The control and experimental groups had a decrease in the number of circular triads, across fewer students. Overall, the circularity in the responses, across too many judges, makes the reliability lower than desirable (Dunn-Rankin, Knezek, Wallace, Zhang, 2012) to reach any supported conclusions.

The experimental and the control groups did have a reduction in the number of circular triads; these groups also had fewer students with circular triads at the end of the intervention. The semiexperimental group stayed relatively the same. Both ends of the spectrum did focus in more on the activities they liked best, but not enough to draw any conclusions of statistical significance at the intended .05 level. While the number of judges was not sufficient for a .05 probability, and the judges' circularity was high, a small shift was observed. Digital fabrication, Interactive websites, model building, and digital content creation were ranked higher on a statistically significantly level over Academic Reading, Self-Connection, and WebQuests in both the pretest and the posttest. The shift that occurred is that the only activities to change in rank position were the top two activities of Interactive Websites and Digital Fabrication. During the pretest these two activities were statistically significantly different at the .05 level with the Interactive Websites being favored. During the posttest however, the two items flipped positions where the digital fabrication was more preferred, but not by enough to be significant on a .05 level.

Academic Measures

The academic section of the pretest was not analyzed until after class intervention type was determined as experimental, semiexperimental, or control group. After the intervention began, pretests were analyzed to determine existing differences. An ANOVA comparison was run on the overall percent scores correct for the three groups (see table 4). There was no statistically significant difference between groups at the time the pretest was administered, as determined by one-way ANOVA $F(2, 68) = .528$, $p = .592$. Additionally, during the initial pretest analysis of the academic measures, the entire academic instrument, the math section of the academic instrument, and the science section of the academic instrument were analyzed; no statistically significant difference was shown via a one-way ANOVA analysis (see Table 4). The one-way ANOVA calculated for the pretest data showed no statistically significant differences between the participants in the groups on any portion of the instrument. Therefore, any differences that emerge in the posttest were not originally evident in the pretest.

Table 4

One-Way ANOVA of Academic Instruments

	Sum of Squares	*df*	Mean Square	*F*	Sig
Whole instrument pretest					
Between groups	169.103	2	84.551	.528	.592
Within groups	10560.665	66	160.010		
Total	10729.768	68			
Math section of pretest					
Between groups	524.963	2	262.481	.986	.379
Within groups	17573.013	66	266.258		
Total	18097.976	68			
Science pretest					
Between groups	508.975	2	254.488	1.106	.337
Within groups	15181.443	66	230.022		
Total	15690.419	68			

Using the posttest data, the overall academic instrument scores, the math section scores, and the science section scores were analyzed on a repeat measures ANOVA (see Table 5). The analysis done on the data for the entire academic instrument revealed no statistically significant differences from the pretest to the posttest. The science portion of the academic assessment showed a statistically significant difference from pretest to posttest $F(1, 66) = 2.434$, $p = .036$ and within the groups from pretest to posttest $F(2, 66) = .911$, $p = .027$. A posthoc Bonferroni correction was performed, though the high level of correction did not show where the significance was within the groups. To have less correction in an attempt to see where the difference was, The Least Significant Difference (LSD) posthoc for the repeat measures was also used. The LSD ANOVA posthoc also did not clarify where the differences were within the groups from the pretest to the posttest. The math section of the academic assessment showed a statistical significance within subjects for the groups from the pretest to the post test *F(*1, 66) = 4.345, *p* = .017.

Table 5

ANOVA Repeat Measures Comparison of Academic Instrument

	Type III Sum of Squares	df	Mean Square	*F*	Sig.	Partial Eta Squared
Full test comparison						
Time	1728.367	1	1728.367	3.673	.060	.053
Time * Section	2150.753	2	1075.377	2.285	.110	.065
Error(time)	31060.116	66	470.608			
Math section comparison						
Time	19.222	1	19.222	2.684	.106	.039
Time * Section	62.240	2	31.120	4.345	.017	.116
Error(time)	472.746	66	7.163			
Science section comparison						
Time	1579.876	1	1579.876	2.434	.124	.036
Time * section	1182.819	2	591.410	.911	.407	.027
Error(time)	42840.933	66	649.105			

As repeat measures ANOVA showed some difference that was not able to be computed via an LSD posthoc, a one-way ANOVA analysis was then performed on the academic posttest instrument, including the individual math and science sections to determine where the significance was coming from. The ANOVA of the posttest was done to understand the findings of the repeat measures ANOVA (see Table 5). The one-way ANOVA showed no statistical difference for the science section during the posttest across the groups. The ANOVA did confirm a statistically significant differences between the groups on the math section of the posttest *F(*1, 66) = 4.235, *p* = .019 (see table 6). The instrument as a whole did show a difference between the groups on the full academic posttest *F(*2, 66) = 3.272, *p* = .044, though, the math section showed a higher significance, while the science section showed no significance.

Table 6

One-way ANOVA of Academic Instruments

	Sum of Squares	df	Mean Square	*F*	Sig.
Whole instrument posttest					
Between groups	1478.971	2	739.485	3.272	.044
Within groups	14914.015	66	225.970		
Total	16392.986	68			
Math section of posttest					
Between groups	2555.978	2	1277.989	4.235	.019
Within groups	19918.570	66	301.797		
Total	22474.548	68			
Science section posttest					
Between Groups	638.247	2	319.124	.994	.376
Within Groups	21197.501	66	321.174		
Total	21835.749	68			

The LSD posthoc of the ANOVA for the entire academic instrument and the math section showed that the experimental group had a statistically significant difference in contrast to the control group on the entire instrument (*p* = .017; see Table 7). The statistical significance was evident because the experimental group's means (with standard deviations) increased from 73.53 (12.52) to 75.58 (15.09), while the means for the control group decreased in performance from 75.94 (12.56) to 64.64 (15.73). The LSD posthoc for the math portion of the academic posttest showed the data for both the experimental and semi- experimental groups to be statistically significant compared to the control group at *p* = .008 and *p*= .48. The experimental group showed the largest increase from pretest to posttest 74.16 (16.67) to 76.56 (14.32). The means for the semiexperimental and the control group decreased from 72.73 (16.47) to 72.31 (16.47) and from 78.90 (15.46) to 62.34 (19.75), respectively. The increase in means for the experimental group pretest to posttest was statistically significant, as was the decrease in the performance of the control group with a Cohen's *d* of .8, found to be a potentially large effect (Cohen, Cohen, West & Aiken, 2003). There was no statistical difference in the means of the semiexperimental group, pretest to posttest.

Table 7

LSD Posthoc ANOVA Multiple Comparisons

(I) section	(J) section	Mean Difference (I-J)	Std Error	Sig
Entire Instrument Posttest				
Experimental	Semiexperimental	3.624	4.708	.444
	Control	10.936*	4.468	.017
Semiexperimental	Experimental	-3.624	4.708	.444
	Control	7.312	4.283	.092
Control	Experimental	-10.936*	4.468	.017
	Semiexperimental	-7.312	4.283	.092
Math Section of Posttest				
Experimental	Semiexperimental	4.24097	5.44078	.438
	Control	14.21736*	5.16357	.008
Semiexperimental	Experimental	-4.24097	5.44078	.438
	Control	9.97639*	4.94939	.048
Control	Experimental	-14.21736*	5.16357	.008
	Semiexperimental	-9.97639*	4.94939	.048
Science Section of Posttest				
Experimental	Semiexperimental	3.668	5.613	.516
	Control	7.456	5.327	.166
Semiexperimental	Experimental	-3.668	5.613	.516
	Control	3.788	5.106	.461
Control	Experimental	-7.456	5.327	.166
	Semiexperimental	-3.788	5.106	.461

As the groups did show some difference on a limited corrected LSD post hoc, a *t*-test was performed on the individual groups that showed a difference to gain insight into which group experienced a change that created the differences across the groups, when no difference existed during the pretest. The *t*-test of the math section of the instrument was performed to see where the differences were meaningful on a $p < .05$ level for the groups from pretest to posttest (see

Table 8). The results showed the control group to have a significant change at *t*(27) = 3.472, *p* = .002. Given that the mean for the control group dropped from 79 (15.46) to 62 (19.75), the statistical significance resulted from the control group's performance on the posttest, confirmed by a decrease of 16.56 (25.24) in the mean.

Table 8

Paired Samples Test for the Math Section of Academic Instrument

	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig.
Group								
Experimental	-2.392	25.143	5.768	-14.511	9.726	-.415	18	.683
Semiexperimental	.413	22.352	4.766	-9.497	10.324	.087	21	.932
Control	16.558	25.239	4.770	6.772	26.345	3.472	27	.002

To further understand the differences within groups from the pretest to posttest, a box and whisker plot of the overall academic measures, the math section, and the science section shows the distribution from each group's pretest and posttest to illustrate the shift that occurred in correlation to the STEM intervention curriculum (see Figure 1).

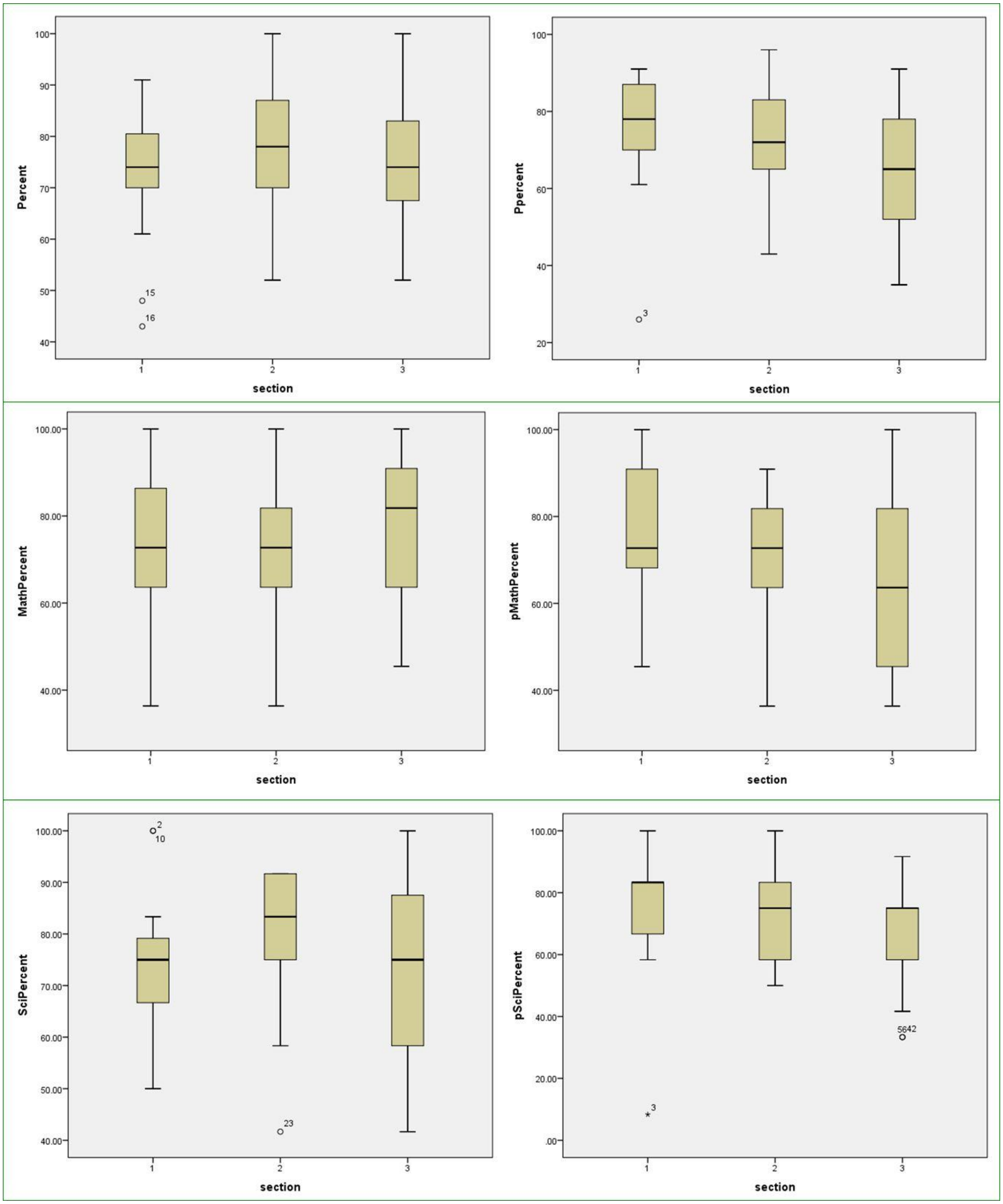

Figure 1. Box and Whisker Comparison from Pretest (left) to Posttest (right).
Group 1 = experimental, Group 2 = semiexperimental, and Section 3 = control.

Likert Data Analysis Overview

Each Likert instrument, the STEM Semantics Survey, the Math Career Interest, the Science Career Interest, and the Academic Assessment Survey-Revised, had individual subscales that were comprised of multiple questions. These questions on each subscale were identified, and the used to be transformed in SPSS as a mean score for each student. These mean subscale scores were used in the data analysis. Each instrument outlines the subscales, though there was a set data analysis process that was followed for all Likert scale instruments with subscales identified from previous studies and instrument development.

Once the subscale means were transformed into a variable, data analysis followed a set routine. The pretests were analyzed with a one-way ANOVA on the subscales was done to determine if groups were different prior to the intervention. After the posttest, the same subscales for the mean were transformed into variables. The pre and post test subscale means were then analyzed with a repeat measures ANOVA to determine if any of the groups changed in different ways from each other from the pretest to the posttest in regards to the individual instrument subscales. A Bonferroni post hoc was done with the ANOVA, though in the even the ANOVA showed significance and the post hoc did not, an LSD post hoc was used to see where the differences where when the correction was not as high.

To further identify any differences as seen through the LSD, a one-way ANOVA was performed on the specific posttest subscales with a Bonferroni post hoc. Though, LSD was most commonly the one to see differences at a $p < .05$ level. To understand why groups had any post test differences as seen through ANOVA measures, a *t*-test was done on the subscales for the groups that showed significance. The *t*-test gave insight into which group experienced a shift that created a significant difference between the groups allowing the research questions to be more accurately explored assessed.

STEM Semantics Survey

The STEM Semantics Survey (SSS) presents pairs of adjectives to the responder that are considered opposites so that they may make an answer selection along a scale of one word to the antonym. The anchors of the Likert range of responses for the adjective pairs used on the instrument was from 1 - 7, with the anchors of 1 being more positive, and less positive when closer to 7. Five subscales exist in the instrument history to show perceptions of (Science), (Technology), (Engineering), (Mathematics), and STEM (Career Interest). The pretest and posttest of the SSS had questions that were reverse measured on the Likert scale. These ten questions, two per subscale, were transformed into new variables that matched the inverse scale on the rest of the questions in the subscales, with a ranking of one being the positive adjective. Data analysis included the transformed variables and not the original user input scale on these reversed responses. The subscales for each instrument were transformed into a means scale for data analysis. During the pretest, the only subscale that showed a statistically significant difference during a one-way ANOVA at the p=.05 level, F(2, 66) = 3.958, p = .024, was the Career subscale (see Table 9).

Table 9

ANOVA Comparison of STEM Semantics Subscales

	Sum of Squares	df	Mean Square	F	Sig.
Science					
Between groups	2.283	2	1.141	1.259	.291
Within groups	59.846	66	.907		
Total	62.129	68			
Math					
Between groups	5.804	2	2.902	1.488	.233
Within groups	128.742	66	1.951		
Total	134.546	68			
English					
Between groups	.150	2	.075	.085	.919
Within groups	58.522	66	.887		
Total	58.672	68			
Technology					
Between groups	2.146	2	1.073	1.761	.180
Within groups	40.226	66	.609		
Total	42.372	68			
Career					
Between groups	8.966	2	4.483	3.958	.024
Within groups	74.767	66	1.133		
Total	83.733	68			

The posthoc analysis showed that a difference on the Career subscale existed between the semiexperimental group and the control group at *p* = .023 (see Table 10). The semiexperimental group had a mean of 1.62 (.72) while the control group had a mean of 2.45 (1.11). The control group was found to have less positive pairings on the Career subscale when compared only to the semiexperiemntal group, and the means for the experimental group fell between the others at 2.26 (1.3).

Table 10

Bonferroni PostHoc Multiple Comparisons of the Career Subscale on the STEM Semantics Survey

				95% Confidence Interval	
	Mean Difference	Std. Error	Sig.	Lower	Upper
Experimental					
Semiexperimental	.64498	.33334	.172	-.1739	1.4638
Control	-.18684	.31636	1.000	-.9640	.5903
Semiexperimental					
Experimental	-.64498	.33334	.172	-1.4638	.1739
Control	-.83182*	.30323	.023	-1.5767	-.0869
Control					
Experimental	.18684	.31636	1.000	-.5903	.9640
Semiexperimental	.83182*	.30323	.023	.0869	1.5767

A repeated measures ANOVA performed after the posttest showed that the Career subscale did not display statistically significant findings within sections or for the intersection of section and time. The means for the control and semiexperimental groups changed very little. For the posttest administration of the survey, the mean for the semiexperimental group was 1.65 (.89), an increase in mean of .03 from the pretest. The control group had a mean decrease of .03 to 2.42 (1.43), pre- to posttest. The experimental groups mean increased .3 to 2.52 (1.46). While groups may have shown a difference during the pretest, there was no significant differences found on the posttest findings at $p < .05$.

The only subscale on the SSS to show a statistical difference was the Math subscale. The statistical significance difference was within subjects for the correlation of groups from the pretest to the posttest $F(1, 2) = 4.838$, $p = .011$ (see table 11) between the groups.

Table 11

Repeated Measures ANOVA Tests of Within-Subjects Contrasts on STEM Semantics Math Subscale

Source	Time	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Linear	1.190	1	1.190	1.777	.187
Time * section	Linear	6.477	2	3.238	4.838	.011
Error(time)	Linear	44.180	66	.669		

The posthoc LSD comparison of the Math subscale showed the control group's mean at 3.93 (1.5) was statistically different from the semiexperimental group at 2.32 (1.1) at $p= .002$ (see table 12). The two groups on the posttest had a Cohen's *d* of -.72, found to be a potentially large effect (Cohen, Cohen, West & Aiken, 2003). The experimental group was between the two at a mean of 2.85 (1.48). Both the experimental and the semiexperimental group experienced a decrease in mean response pre- to posttest while the mean for the control group increased, creating the statistical significance. The H_7 was not supported with this instrument. The H_1 was supported as both groups became more positive in their perceptions of Math.

Table 12

Repeated Measures ANOVA Math Subscale LSD Posthoc

	Mean Difference	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower	Upper
Experimental					
Semiexperimental	.483	.395	.225	-.305	1.272
Control	-.664	.375	.081	-1.412	.085
Semiexperimental					
Experimental	-.483	.395	.225	-1.272	.305
Control	-1.147*	.359	.002	-1.865	-.430
Control					
Experimental	.664	.375	.081	-.085	1.412
Semiexperimental	1.147*	.359	.002	.430	1.865

A *t*-test was performed for the responses on the Math subscale from the SSS to determine if any of the increases or decreases in means for the groups were statistically significant (see Table 13). The *t*-test showed only the control group to have a significant change at *t*(27) = -3.33, *p* = .003. The control group had an effect size *d* of .506, found to be a potentially medium effect (Cohen, Cohen, West & Aiken, 2003). Given that the mean increased from 3.16 (1.55) to 3.93 (1.5), the statistical significance resulted because the data from the control group showed a less positive correlation on the subscale for Math, with an increase of -.77 (1.22) in the mean, as opposed to a large change in the other groups.

Table 13

t-test Paired Differences From STEM Semantics Survey Pretest to Posttest

	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Experimental								
Science	.09474	.63725	.14619	-.21241	.40188	.648	18	.525
Math	.05263	1.17916	.27052	-.51570	.62097	.195	18	.848
Engineering	.08421	.77836	.17857	-.29095	.45937	.472	18	.643
Career	-.25263	.79678	.18279	-.63667	.13140	-1.382	18	.184
Semiexperimental								
Science	.13636	.45518	.09704	-.06545	.33818	1.405	21	.175
Math	.15455	1.04185	.22212	-.30739	.61648	.696	21	.494
Engineering	.02727	.62730	.13374	-.25086	.30540	.204	21	.840
Career	-.03636	.63437	.13525	-.31763	.24490	-.269	21	.791
Control								
Science	.20000	.87939	.16619	-.14099	.54099	1.203	27	.239
Math	-.77143	1.22531	.23156	-1.24655	-.29630	-3.331	27	.003
Engineering	-.03571	.86590	.16364	-.37148	.30005	-.218	27	.829
Career	.02857	1.05369	.19913	-.38001	.43715	.143	27	.887

Science Career Interest Instrument

The Likert-like scale of adjective pairings for the Science Career Interest (SCI) instrument consists of more positive pairings at 1, with the negative pairings on the other end of the scale at 5. The SCI has three subscales— perception of (support) on the path to a science career, interest in (education) opportunities building to a science career, and the perceived important of (career) in science (Tyler-Wood, Kenezek, Christensen, 2010). The responses to the questions that comprised these three subscales were transformed into a mean for each participant and analyzed. For the administration of the pretest, the data for the subscale for Education and Career interest showed a statistically significant difference. The Education subscale was significant at *F(*2, 66) = 3.35, *p* = .041, with the career subscale statistically significant at *F(*2, 66) = 3.13, *p* = .050 (see Table 14).

Table 14

ANOVA Comparison of Pretest Measures

	Sum of Squares	df	Mean Square	F	Sig.
Support					
Between groups	1.567	2	.783	1.177	.314
Within groups	43.919	66	.665		
Total	45.486	68			
Education					
Between groups	4.908	2	2.454	3.351	.041
Within groups	48.338	66	.732		
Total	53.246	68			
Career					
Between groups	1.683	2	.841	3.130	.050
Within groups	17.741	66	.269		
Total	19.424	68			

The ANOVA Bonferroni posthoc test showed a significant difference for the Education subscale on the SCI at *p*=.036, between the mean of the semiexperimental group at 3.65 (.82), which was less positive on the subscale, and the control group mean at 3.01 (.94) (see Table 15).

The Career subscale showed a statistically significant difference to be between the experimental and the semiexperimental group but this difference was not statistically significant on a Bonferroni posthoc at *p*=.056.

Table 15

Multiple Comparisons Bonferroni Post Hoc Comparison of Groups on Subscales

(I) section	(J) section	Mean Difference	Std. Error	Sig.	95% Confidence Interval Lower	Upper
Education						
Experimental	Semiexperimental	-.35072	.26803	.586	-1.0091	.3077
	Control	.28045	.25437	.823	-.3444	.9053
Semiexperimental	Experimental	.35072	.26803	.586	-.3077	1.0091
	Control	.63117*	.24382	.036	.0322	1.2301
Control	Experimental	-.28045	.25437	.823	-.9053	.3444
	Semiexperimental	-.63117*	.24382	.036	-1.2301	-.0322
Career						
Experimental	Semiexperimental	-.39155	.16238	.056	-.7904	.0073
	Control	-.12531	.15410	1.000	-.5039	.2532
Semiexperimental	Experimental	.39155	.16238	.056	-.0073	.7904
	Control	.26623	.14771	.228	-.0966	.6291
Control	Experimental	.12531	.15410	1.000	-.2532	.5039
	Semiexperimental	-.26623	.14771	.228	-.6291	.0966

After the posttest administration of the SCI, a repeated measures ANOVA was performed on all three individual subscales of the instrument. Only the Education subscale indicated a statistically significant difference *F(*1, 2) = 6.819, *p* = .002 within groups from the pretest to the posttest (see Table 16).

Table 16

Tests of Within-Subjects Contrasts for the Education Subscale for the Science Career Interest

	Type III Sum of Squares	df	Mean Square	F	Sig.
Education					
Time	.022	1	.022	.171	.681
Time * section	1.721	2	.861	6.819	.002
Error(time)	8.331	66	.126		

The LSD post hoc comparison of the groups on the Education subscale showed the *p*= .049 statistically significant difference to be between the semiexperimental group and the control group (see table 17). The data for the semiexperimental group exhibited a decrease in the means from 3.65 (.82) to 3.6 (.76), while the experimental group experienced an increase from 3.01 (.88) to 3.34 (.86). The experimental group also experienced a decrease in the means, from 3.29 (.76) to 3.09 (.71).

Table 17

ANOVA Posthoc Pairwise Comparisons

(I) section	(J) section	Mean Difference	Std. Error	Sig.	95% Confidence Interval Lower	Upper
Education						
Experimental	Semiexperimental	-.428	.245	.086	-.918	.062
	Control	.020	.233	.933	-.445	.485
Semiexperimental	Experimental	.428	.245	.086	-.062	.918
	Control	.448*	.223	.049	.002	.894
Control	Experimental	-.020	.233	.933	-.485	.445
	Semiexperimental	-.448*	.223	.049	-.894	-.002

Further investigation was done with a dependent *t*-test to gain additional insight into the shifts on the SCI (see Table 18). The education subscale was analyzed first, because that data showed a statistically different difference during the pretest. The experimental group showed a statistically significant difference at t(18) = 2.67, *p*= .016, with the mean decreasing from 3.29 (.77) to 3.09 (.71), which was a change of .2 (.06). The experimental group had an effect size *d* of .265, found to be a potentially small effect (Cohen, Cohen, West & Aiken, 2003).The control group also displayed a statistically significant difference at the t(27) = -3.07, *p*=.005 levels, with the means increasing from 3.01 (.94) to 3.34 (.86), and a change of -.32 (.55). The control group had an effect size *d* of .355, found to be a potentially small effect (Cohen, Cohen, West & Aiken, 2003). For the Education subscale of the SCI, the responses from the experimental group shifted towards being more positive while the control group also shifted but toward the negative end of the response scale. Moreover, the control group also showed a statistically significant difference at t(27) = 2.67, *p*=.028 for the Support subscale, with the means increasing from 3.5 (.74) to 3.6 (.78), a change of -.18 (.4 m). The control group on the t-test had an effect size *d* of .235, found to be a potentially small effect (Cohen, Cohen, West & Aiken, 2003).

Table 18

T-test Paired Differences From STEM Semantics Pretest to Posttest

	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	*t*	df	Sig.
Groups								
Experimental								
Support	-.06579	.42363	.09719	-.26997	.13839	-.677	18	.507
Education	.20000	.32660	.07493	.04258	.35742	2.669	18	.016
STEM Career	.00000	.65734	.15080	-.31683	.31683	.000	18	1.000
Semiexperimental								
Support	-.09091	.76199	.16246	-.42876	.24694	-.560	21	.582
Education	.04545	.55526	.11838	-.20073	.29164	.384	21	.705
STEM Career	-.03030	.45900	.09786	-.23381	.17320	-.310	21	.760
Control								
Support	-.17857	.40744	.07700	-.33656	-.02058	-2.319	27	.028
Education	-.32143	.55334	.10457	-.53599	-.10686	-3.074	27	.005
STEM Career	-.13095	.56174	.10616	-.34877	.08687	-1.234	27	.228

Math Career Interest

The Math Career Interest (MCI) instrument presents paired adjectives to the responders, where they choose a response on the Likert-like scale. The correlation of 1 is a more positive response and 5 is a less positive adjective in the pair. The MCI has three subscales— perception of (support) on the path to a math career, interest in (education) opportunities building to a math career, and the perceived important of (career) in math (Tyler-Wood, Kenezek, Christensen, 2010). The responses for the adjective pairs of these three subscales were transformed into a mean for each participant and analyzed. During the pretest, a one-way ANOVA noted a statistical difference at the p < .05 level between the groups on both the subscales of Support, *F(*2, 68) = 3.226, p = .046; and Education, *F*(2, 66) = 5.094, p = .009 (see table 19).

Table 19

ANOVA Comparison of Pretest for the Math Career Interest

	Sum of Squares	df	Mean Square	F	Sig.
Support					
Between groups	4.255	2	2.128	3.226	.046
Within groups	43.529	66	.660		
Total	47.784	68			
Education					
Between groups	6.805	2	3.402	5.094	.009
Within groups	44.083	66	.668		
Total	50.888	68			
Career					
Between groups	.902	2	.451	1.578	.214
Within groups	18.850	66	.286		
Total	19.752	68			

The Bonferroni posthoc comparison of the pretest MCI support subscale showed a difference at p = .040 between the semiexperimental group (less positive with a mean of 3.45 ± .99) and the control group (more positive at 3.19 ± .8 m, see Table 20). The Education subscale of the MCI showed a statistically significant difference for means at *p*= .007 between the semiexperimental group (less positive at 3.66 (.71)) and the control group (more positive at 2.92 (.80)). On the Education and Support subscales, the control group was the most positive and the other groups less positive.

Table 20

ANOVA Bonferroni Posthoc Multiple Comparisons of Math Pretest Subscales

(I) section	(J) section	Mean Difference	Std. Error	Sig.	95% Confidence Interval Lower	95% Confidence Interval Upper
Support						
Experimental	Semiexperimental	-.33672	.25434	.570	-.9615	.2881
	Control	.25094	.24138	.907	-.3420	.8439
Semiexperimental	Experimental	.33672	.25434	.570	-.2881	.9615
	Control	.58766*	.23137	.040	.0193	1.1560
Control	Experimental	-.25094	.24138	.907	-.8439	.3420
	Semiexperimental	-.58766*	.23137	.040	-1.1560	-.0193
Education						
Experimental	Semiexperimental	-.37943	.25596	.429	-1.0082	.2493
	Control	.36278	.24292	.420	-.2340	.9595
Semiexperimental	Experimental	.37943	.25596	.429	-.2493	1.0082
	Control	.74221*	.23284	.007	.1702	1.3142
Control	Experimental	-.36278	.24292	.420	-.9595	.2340
	Semiexperimental	-.74221*	.23284	.007	-1.3142	-.1702

A repeat measures ANOVA was used on the MCI to see if data for the groups changed from pretest to posttest. However, no groups showed a statistically significant difference. As there were differences in the pretest one-way ANOVA for the Support and Education subscales, a one-way ANOVA was also run on the data for the posttest administration of the instrument to determine if the same differences persisted or changed (see table 21). The one-way ANOVA of the posttest showed that there was no longer a statistically significant difference on the Education subscale because the means for the experimental and semiexperimental groups decreased towards more positive adjectives while the mean for the control group increased —closing the gap that existed during the pretest phase. The subscale that did show a statistical significance during the posttest was the Support subscale at $F(2, 68) = 3.47$, p = .037.

Table 21

ANOVA Comparison of Pretest for the Math Career Interest

	Sum of Squares	df	Mean Square	F	Sig.
Support					
Between groups	4.565	2	2.283	3.469	.037
Within groups	43.430	66	.658		
Total	47.995	68			
Education					
Between groups	2.164	2	1.082	1.783	.176
Within groups	40.039	66	.607		
Total	42.203	68			
Career					
Between groups	2.549	2	1.274	3.075	.053
Within groups	27.358	66	.415		
Total	29.907	68			

The Bonferroni posthoc for the posttest of the MCI instrument showed the differences in the Support subscale to be between the semiexperimental and the control group at $p=.034$ (see Table 22). The differences in the group had a Cohen's *d* of .089, found to be a potentially small effect (Cohen, Cohen, West & Aiken, 2003). The group means stayed consistent from pretest to posttest. Due to the consistent difference in the subscales across the groups, a *t*-test was also performed to further analyze for any changes amongst the groups that occurred from pretest to posttest. The *t*-test showed the semiexperimental group to be the only group to show a statistical difference. The Education subscale on the *t*-test showed a statistically significant difference at $t(21) = 2.17$, $p= .042$, with the means decreasing from 3.66 (.71) to 3.14 (.73), a change of .245 (.53) (see Table 23). The semiexperimental group became more positively correlated with the Education subscale on the MCI instrument, with an effect size *d* of .366, found to be a potentially small effect (Cohen, Cohen, West & Aiken, 2003).

Table 22

ANOVA Posthoc Pairwise Comparisons for Math Sub Scales

(I) section	(J) section	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower	Upper
Support						
Experimental	Semiexperimental	-.25957	.25405	.932	-.8837	.3645
	Control	.34352	.24111	.477	-.2488	.9358
Semiexperimental	Experimental	.25957	.25405	.932	-.3645	.8837
	Control	.60308*	.23111	.034	.0354	1.1708
Control	Experimental	-.34352	.24111	.477	-.9358	.2488
	Semiexperimental	-.60308*	.23111	.034	-1.1708	-.0354
Education						
Experimental	Semiexperimental	-.26029	.24393	.870	-.8595	.3389
	Control	.15789	.23151	1.000	-.4108	.7266
Semiexperimental	Experimental	.26029	.24393	.870	-.3389	.8595
	Control	.41818	.22190	.192	-.1269	.9633
Control	Experimental	-.15789	.23151	1.000	-.7266	.4108
	Semiexperimental	-.41818	.22190	.192	-.9633	.1269
Career						
Experimental	Semiexperimental	-.41866	.20164	.125	-.9140	.0767
	Control	-.01065	.19136	1.000	-.4807	.4594
Semiexperimental	Experimental	.41866	.20164	.125	-.0767	.9140
	Control	.40801	.18343	.089	-.0426	.8586
Control	Experimental	.01065	.19136	1.000	-.4594	.4807
	Semiexperimental	-.40801	.18343	.089	-.8586	.0426

Table 23

T-Test Paired Differences from STEM Semantics Pretest to Posttest

	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Groups								
Experimental								
Support	-.06579	.54545	.12513	-.32869	.19711	-.526	18	.605
Education	.12632	.61178	.14035	-.16855	.42118	.900	18	.380
Career	.10526	.53348	.12239	-.15187	.36239	.860	18	.401
Semiexperimental								
Support	.01136	.47231	.10070	-.19805	.22078	.113	21	.911
Education	.24545	.53070	.11315	.01015	.48075	2.169	21	.042
Career	-.09091	.49529	.10560	-.31051	.12869	-.861	21	.399
Control								
Support	.02679	.50616	.09566	-.16948	.22306	.280	27	.782
Education	-.07857	.56395	.10658	-.29725	.14011	-.737	27	.467
Career	.05952	.76472	.14452	-.23701	.35605	.412	27	.684

School Attitude Assessment Survey-Revised

The School Attitude Assessment Survey-Revised (SAAS-R) is a Likert-like scale instrument where 1 = *strongly disagree* with the positive statement and 7 = *strongly agree* with the positive statement. The instrument contains five subscale constructs: Academic Self-Perceptions, Attitudes Toward Teachers and Classes, Attitudes Toward School, Goal Valuation, and Motivation/Self-Regulation. The responses to the questions that comprised these subscales were transformed into separate means for each participant and analyzed. The one-way ANOVA run on the pretest subscales showed no statistically significant differences between the groups.

After the administration of the posttest, a repeated measures ANOVA was performed. The ANOVA showed that two subscales, Attitude Towards Teachers and Classes, and the Attitudes Toward School, had a statistically significant difference from the pre- to the posttest: Attitudes Towards Teachers and Classes *F(*1, 2) = 9.689, p = .003 and Attitudes Toward School *F(*1, 2) = 9.993, p = .002, (see table 24).

Table 24

Tests of Within-Subjects Contrasts for School Attitude Assessment Survey-Revised

Source	Time	Type III Sum of Squares	df	Mean Square	F	Sig.
Attitudes Towards Teacher and Classes						
time	linear	2.249	1	2.249	9.689	.003
time * section	linear	.498	2	.249	1.074	.348
error(time)	linear	15.316	66	.232		
Attitudes Towards School						
time	linear	4.363	1	4.363	9.993	.002
time * section	linear	.316	2	.158	.362	.697
error(time)	linear	28.815	66	.437		

However, a posthoc comparison did not show any statistical differences between any groups on these subscales. Since the repeat measures ANOVA showed a difference from pretest to posttest, a follow-up paired samples *t*-test was performed on the individual groups from pretest to post to see if the effect of time showed a significance, even if it was not different across all groups. The *t*-test did reveal that the experimental group had a statistically significant decrease in scores on the Attitudes Towards Teacher and classes and Attitudes Towards School subscales at t(18) = 3.012, *p*=.007, from a pretest mean of 6.23 (.729) to a posttest mean 5.93 (.97) (see Table 25). The experimental group also had a statistically significant difference in scores on the Attitudes Towards School subscale at *t*(18) = 2.249, *p*=.037, from pretest mean of 6.43 (. 749) to a posttest mean of 6.08 (1.04). The experimental group had an effect size *d* of

.326 and .321 respectively, found to be a potentially small effect (Cohen, Cohen, West & Aiken, 2003).

The responses for the semiexperimental group showed no statistically significant changes from pretest to post in the paired samples *t*-test. The control group did experience a statistically significant shift on both the Attitudes Towards Teacher and classes and Attitudes Towards School subscales. The Attitudes Towards Teacher and Classes and Attitudes Towards School subscales showed that for t(27) = 2.460, *p*= .021, there was a decrease in the means from 6.15 (.490) to 5.78 (.87) from pretest to posttest. The control group also had a statistically significant difference t(27) = 2.01, *p*= .050 in scores on the Attitudes Towards School subscale from a pretest mean of 6.36 (.762) to a posttest mean of 5.89 (1.51). The control group had an effect size *d* of .510 for the Attitudes Towards Teacher and Classes and .35 for the Attitudes towards school, found to be a potentially medium and small effect (Cohen, Cohen, West & Aiken, 2003).

Table 25

Paired Samples Test for the for School Attitude Assessment Survey-Revised
Attitudes Towards Teacher and classes (ATTC) and Attitudes Towards School (ATS)

	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig.
				Lower	Upper			
Experimental								
Pre/post ATTC	.30075	.58301	.13375	.01975	.58175	2.249	18	.037
Pre/Post ATS	.34737	.50262	.11531	.10511	.58963	3.012	18	.007
Semiexperimental								
Pre/post ATTC	.09740	.56525	.12051	-.15322	.34802	.808	21	.428
Pre/Post ATS	.25455	.75890	.16180	-.08193	.59102	1.573	21	.131
Control								
Pre/post ATTC	.37755	.81205	.15346	.06267	.69243	2.460	27	.021
Pre/Post ATS	.47857	1.23209	.23284	.00082	.95633	2.055	27	.050

On the Likert-scaled School Attitude Assessment Survey-Revised instrument, all groups experienced a negative shift on four of the five subscales (Academic Self-Perceptions, Attitudes Toward Teachers and Classes, Attitudes Toward School, Goal Valuation, and Motivation/Self-Regulation). The semiexperimental and the control group did not experience a change in the fifth construct of Goal Valuation. The experimental group did show a negative shift in the goal Valuation, but not for the Motivation/Self-Regulation subscale.

To further understand any changes that occurred over the 20 hours of intervention, the group means were compared on all instruments from pretest to posttest in a means comparison (see table 26). On the STEM-focused Likert-scaled instruments, the control group became more positive on three subscales: SSS Career, and the MCI Support and MCI Career subscales. The experimental group became more positive on five subscales, which overlapped with four of the five shifts in the semiexperimental group. The overlapping subscale shift towards the positive adjective pairings were for the SSS Math and Engineering scales, the SCI Education subscale, and the MCI Education. The experimental group also had a positive shift on the subscale of Career for the MCI. In addition, the semiexperimental group also showed a positive shift on the MCI on the Support subscale.

Table 26

Mean Comparison of all instrument subscales

Group			Experimental		Semiexperimental		Control	
Number of Participants			19		22		28	
			Mean	SD	Mean	SD	Mean	SD
Academic Instrument								
	Whole Instrument	Pre	73.53	12.52	77.50	12.88	76.36	12.56
		Post	75.58	15.09	71.95	14.03	64.64	15.73
	Science Portion	Pre	72.81	13.84	79.17	13.30	73.81	17.23
		Post	74.12	20.20	70.45	18.50	66.67	15.71
	Math Section	Pre	74.16	16.67	72.73	17.07	78.90	15.46
		Post	76.56	14.32	72.31	16.47	62.34	19.75
STEM Semantics Survey								
	Science	Pre	2.16	1.03	1.84	0.94	2.26	0.91
		Post	2.06	1.07	1.70	0.90	2.06	0.87
	Math	Pre	2.91	1.41	2.47	1.16	3.16	1.55
		Post	2.85	1.48	2.32	1.10	3.93	1.50
	Engineering	Pre	1.92	1.06	1.91	0.95	2.01	0.85
		Post	1.83	1.17	1.88	1.03	2.04	0.87
	Technology	Pre	1.88	0.94	1.43	0.60	1.67	0.79
		Post	1.88	0.94	1.43	0.60	1.67	0.79
	STEM Career	Pre	2.26	1.30	1.62	0.72	2.45	1.11
		Post	2.52	1.46	1.65	0.89	2.42	1.43
Science Career Interest								
	Support	Pre	3.42	0.85	3.78	0.88	3.50	0.74
		Post	3.49	0.87	3.88	0.90	3.68	0.78
	Education	Pre	3.29	0.77	3.65	0.82	3.01	0.94
		Post	3.09	0.71	3.60	0.76	3.34	0.86
	Career	Pre	4.02	0.54	4.41	0.56	4.14	0.47
		Post	4.02	0.58	4.44	0.52	4.27	0.44
Math Career Interest								
	Support	Pre	3.45	0.99	3.78	0.63	3.20	0.80
		Post	3.51	0.97	3.77	0.69	3.17	0.78
	Education	Pre	3.28	0.94	3.66	0.71	2.92	0.80
		Post	3.16	0.95	3.42	0.73	3.00	0.68
	Career	Pre	4.04	0.64	4.26	0.57	4.00	0.42
		Post	3.93	0.57	4.35	0.57	3.94	0.74

Table 26 Cont.

Group		Experimental		Semiexperimental		Control	
Number of Participants		19		22		28	
		Mean	SD	Mean	SD	Mean	SD
School Attitude Assessment Survey Revised							
Academic Self-Perceptions	Pre	5.88	0.71	6.09	0.62	5.97	0.57
	Post	5.84	0.73	5.89	0.64	5.93	0.68
Attitudes Towards Teacher and classes	Pre	6.23	0.73	6.05	0.71	6.15	0.49
	Post	5.93	0.97	5.95	0.62	5.78	0.87
Attitudes Towards School	Pre	6.43	0.75	6.37	0.67	6.36	0.76
	Post	6.08	1.04	6.12	0.76	5.89	1.51
Goal Valuation	Pre	6.78	0.30	6.64	0.47	6.79	0.31
	Post	6.67	0.38	6.64	0.56	6.79	0.51
Motivation/ Self-Regulation	Pre	6.00	0.63	6.13	0.75	6.09	0.53
	Post	6.04	0.78	6.01	0.71	5.98	0.71

Instruments Overview

To further understand the findings on each instrument, an internal reliability analysis of Cronbach’s alpha was performed. Internal reliability represents the internal linking of concepts within an instrument measuring the homogeneity within that instrument (DeVellis, 1991). The internal reliability is stronger as the number approaches 1, with anything over .8 being good consistency and over .9 being excellent consistency for an educational study. Since the main focus of this study was on the differences between the groups from pretest to posttest, Cronbach’s alpha was identified for each group across all instruments on the pretests and posttests to determine if each administration of the instruments was internally consistent, to reveal if change occurred from reliable internal constructs of the instruments. The majority of the instruments showed high internal reliability, meaning that the responses across all three instruments were generally consistent (see Table 27).

Table 27

The table shows the Cronbach alphas for each instrument for the individual groups tested.

	Experimental	Semiexperimental	Control	Whole
STEM Survey				
Pretest	.959	.891	.883	.923
Post Test	.966	.911	.903	.935
Science Career Interest				
Pretest	.888	.923	.919	.916
Posttest	.852	.927	.913	.910
Math Career Interest				
Pretest	.909	.882	.901	.909
Posttest	.875	.896	.823	.874
School Attitude Assessment Survey - Revised				
Pretest	.932	.954	.922	.936
Posttest	.905	.932	.935	.925

For this study, some groups did display a drop or raise in the Cronbach Alpha for the whole instrument across the three groups from pretest to posttest, but for all survey instruments, the Cronbach's alpha for all groups still ranged from good (.823) to excellent (.966) (see table 27), showing that there was a homogeneity to the internal constructs within the instruments. The changes from pretest to posttest, or amongst groups, occurred from instruments that showed internal reliability on the constructs.

CHAPTER 5

DISCUSSION

Knowledge Learned

Academic Measures Instrument

The data analysis showed that some changes occurred across the groups from the start of the intervention to the end of the experimental phase. The academic pretests showed that the groups were not statistically different. When the average scores for individual questions from the academic instrument were compared to the TIMSS averages for the United States and international averages, students performed higher on the posttest than the historical averages for those duplicated questions in both the math and science sections. The questions on the posttest were different paired questions, so the improvement was not from being exposed to the same questions twice. The whole instrument showed a difference from pretest to posttest, however the difference was not from a difference in the science section, but rather, the math portion of the instrument. There was a positive shift for the experimental groups in the academic performance on a statistically significant level for the math section of the posttest, with the control group actually scoring lower posttest on the math section. At the same time, the experimental group scored higher on the posttest compared to the pretest, though not at a statistically significant level. The experimental and semiexperimental group both had higher averages on the math section of the academic measures instrument on a statistically significant level. The experimental group had the highest average performance on the posttest, followed by the semiexperimental group, and then the control group. The experimental and the semiexperimental group both increased in their math performance, while the control group’s performance decreased.

STEM Semantics Survey

The results of the SSS analysis showed groups to be different on the Career scale in the pretest but groups evened out for the posttest. For the pretest administration of the survey, the Math subscale showed no differences between the groups. However, there were differences between the groups posttest. The Math subscale of the SSS for the control group shifted in a negative direction at a statistically significant level while the semiexperimental and experimental groups shifted more positive. The shift towards a more positive perception may have a correlation to the experimental and semiexperimental groups' increased performance on the academic measures. The negative perceptions of math recorded for the control groups may be correlated with the decrease in the posttest responses for the Academic Measures instrument. The H_1 was supported over the H_0.

Math Career Interest

The MCI pretest did show the groups to have some differences at a significant level for the subscales of Support and Education. The control group on both these subscales had more positive perceptions than the experimental groups. There was no statistically significant difference between the groups on the Education subscale. At the time of the posttest, all three groups maintained the statistical difference from the pretest administration of the instrument on the Support subscale, without any statistically significant changes in the Career subscale on the pretest. However, there was not a statistically significant change in the Career subscale from the pretest. The reason for this is that the control group became more negative in their perceptions while the semiexperimental group became more positive at a statistically significant level. The MCI substantiated the observed shift in the math academic measures, in that a shift in perceptions of the experimental transmedia book groups, both with and without the 2D cutter and

3D printer. The experimental groups had higher academic scores and became more positive with their math perceptions on both the SSS and MCI instruments. Supporting the H_2 as a consistent shift in the way they perceived and succeeded at math.

Science Career Interest

The SCI showed similar results to the MCI on the pretest. For the pretest administration of the instruments, the Education subscale and the Career subscale showed a statistically significant difference between the groups. The difference on the Education subscale was again between the control group and the semiexperimental group, with the control group being more positive during the pretest. The posttest showed the control group became more negative, while the experimental group became more positive on a statistically significant level. The semiexperimental group did not show any statistically significant differences. The control group also became more negative in regards to their perception of support, while the other groups did not show a statistical significance for their more negative shifts.

The School Attitude Assessment Survey - Revised

The SAAS - R showed no statistically significant differences between the groups on the subscales. All groups did experience a shift in their Attitudes Towards Teacher and Classes, and Attitudes Towards School. The shifts for the control group and the experimental group both became more negative on a statistically significant level. Since all groups experienced a shift, it is possible that the students’ high expectations at the start of the year during the second week of school were not met during the final week of the first grading cycle, or perhaps other extraneous factors in their math or science classes negatively impacted them.

Summary

The total class time during the intervention was under 20 hours. Students did experience a math perception shift after being exposed to the STEM transmedia book. While student interest in math as a career did not change, it did show that it was valued more after the intervention. The change in math perception also correlated to higher math achievement for the experimental group. All students' attitudes towards school changed, though not one group alone stood out to draw any correlations with the intervention or non-intervention groups. Students did have more of a consistent preference of STEM activities, though they still were generally inconsistent in their preferences. The transmedia STEM intervention book did show to have some correlation to math perception and achievement during the relatively short intervention period.

Despite length of the intervention, this study showed some avenues for future focused study. Namely, that the two experimental groups experienced a positive shift in their math scores and their math perceptions whereas the control group became less positive on the same math items. The control groups' experiences may not have lived up to their expectations, as they started very positive. It may be possible that all three groups experienced something in their other classes that gave them a more negative perspective of their teachers and school. However, while all groups shifted in the same negative direction, the experimental groups shift was not as big, and they still became more positive about math as a whole.

Cautions for Future Studies

One of the biggest cautions for the future was a repeat from the pilot study. Technology access was restricted for some student in both the pilot and current study. Technology in schools can change without notice. Therefore, checking for technology accessibility more than a few days in advance can lead to unexpected changes that can delay the experiment. The pilot study had been done with all 8th graders in the past because those students would move to high school and not impact future participants in the study. However, the 8th graders were tested at the end of the academic year and the current study was administered to students at the start of their seventh grade year. The change from end-of-the-year 8th graders in the pilot to start-of-the-year 7th graders in the study created an unexpected gap in student ages. Age affects the types of technology access that is available to students in this school district— web filters and E-mail filters, as well as general technology access. The level of access could not be changed for the study, as it automatically adjusts for each student on their birthday each year. This discovery was not made until after contacting the district's technology department about why some students had access and others did not. The lesson of asking specific questions about the technology to be used is of the utmost importance. For purposes of replication, it is advised to inquire about these items with the district technology department:

1. Are these specific websites accessible to all students, and if not, can they be made available for the duration of this study?
2. Are there any technology permissions or access managed by an automated system?
3. Are there any technology permissions or access that are age-based?
4. Are there any upcoming changes for the technology use, access, or systems that will be enacted in classrooms over the next year?
5. What does the software and hardware approval system involve and how long does the process normally take?

6. Is there a list of currently accessible software to inspect for similar software that already exists on the computers that will be used for the study, and, if so, is it accessible to the group of students to be studied?

Limitations of Study

The study was mainly limited by the inability to randomly select participants across the experimental groups. The three groups compared in the study were used because they were students entering their first year of a STEM elective at a middle school. All students who were entering this elective did display similar interest at the start of the intervention since, for the most part, the majority of students self-selected to be in the elective class. The groups, while not randomized, did show relative similarity in pretest administrations of the study instruments, without one group scoring significantly better or being more interested in any one STEM category or academic measure. The divergence in the posttest can reasonably be contributed to the intervention, as all students across all groups would have experienced the same outside factors from their other classes at the same school. However, not many differences were found. The actual amount of time students spent in their elective class working on the transmedia book project was under 20 hours. Given the limited time students were actually involved in the study, perhaps an intervention spanning a few weeks was not long enough for the intervention to drastically change perceptions of middle school STEM elective students. However, some sparks of change did emerge that could be further studied to increase the impact of a STEM intervention transmedia book.

Future Studies

An important note for future studies is that the students who participated in this study experienced a constructivist environment. In this study to gather supporting evidence for a specific research questions a quantitative study was used, but further qualitative analysis could support or provide insights into why some subscales, such as the math measures, showed a difference. Having both students and teachers participate in the pretest and posttest measures could show if teacher perceptions correlate with student changes. Another variable to check for would be student growth compared to the teachers' initial perceptions and knowledge level. Having the why support the changes could help give professionals in the education field the insight they need to give the intervention a try, and create a long term change. A transformative study could also be completed in which qualitative focus is added to explain why students experience the changes they do from pretest to posttest during the intervention curriculum.

REFERENCES

Academic. (3rd ed.). (2000). The American heritage college dictionary. Boston: NY.

Aliyu, A. A., Bello, M. U., Kasim, R., & Martin, D. (2014). Positivist and non-positivist paradigm in social science research: Conflicting paradigms or perfect partners ? *Journal of Management and Sustainability*, *4*(3), 79-95. doi:10.5539/jms.v4n3p79

Alozie, N., Eklund, J., Rogat, A., & Krajcik, J. (2010). Genetics in the 21st century: The benefits & challenges of incorporating a project-based genetics unit in biology classrooms. *The American Biology Teacher*, *72*(M), 225-230.

Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research. *Educational Researcher*, *41*(1), 16-25. doi:10.3102/0013189X11428813

Applebee, A., Adler, M., & Flihan, S. (2007). Interdisciplinary curricula in middle and high school classrooms: Case studies of approaches to curriculum and instruction. *American Educational Research Journal*, *44*(4), 1002-1039.

Aqeel, A., & Awwad, A. (2013). Piaget's theory of learning. *Interdisciplinary Journal of Contemporary Research in Business*, *4*(9), 106-130.

Askenasy, J., Lehmann, J., Perry, E. K., & Voss, U. (2013). Consciousness, brain, neuroplasticity. *Frontiers In Psychology*, *4*1-10. doi:10.3389/fpsyg.2013.00412

Bamberger, Y. M., & Cahill, C. S. (2012). Teaching design in middle-school: Instructors' concerns and scaffolding strategies. *Journal of Science Education and Technology*, *22*(2), 171-185. doi:10.1007/s10956-012-9384-x

Beauchamp, G. (1982). Curriculum theory: Meaning, development, and use. *Theory into Practice*, *21*(1), 23-27.

Bernstein, R. J. (1992). *The new constellation: The ethical-political horizons of modernity/postmodernity*. Cambridge: Massachusetts. MIT press.

Berry, R. Q., Bull, G., Browning, C., Thomas, C. D., Starkweather, G. & Aylor, J. (2010). Use of digital fabrication to incorporate engineering design principles in elementary mathematics education. *Contemporary Issues in Technology and Teacher Education, 10*(2), 167-172. Association for the Advancement of Computing in Education (AACE). Retrieved from: http://www.editlib.org/p/35289/

Boghossian, P. (2006). Behaviorism, constructivism, and Socratic pedagogy. *Educational Philosophy and Theory*, *38*(6). Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1469-5812.2006.00226.x/full

Boschman, F., McKenney, S., & Voogt, J. (2014). Understanding decision making in teachers' curriculum design approaches. *Educational Technology Research and Development*, *62*(4), 393-416. doi:10.1007/s11423-014-9341-x

Brusilovsky, P. (2001). Adaptive hypermedia. *User Modeling and User-Adapted Interaction*, *11*, 87-110.

Burkhardt, H. (2014). Mathematics curriculum in school education. *Mathematics Curriculum in School Education*, *xi*(663), 13-35. doi:10.1007/978-94-007-7560-2

Cakir, M. (2008). Constructivist approaches to learning in science and their implications for science pedagogy: A literature review. *International Journal of Environmental & Science*, *3*(4), 193-206.

Carnevale, A., Smith, N., & Melton, M. (2011). Georgetown University Center on Education and the Workforce. *STEM executive summary*. Washington, DC: DC20007.

Center for the Study of Mathematics. (2012). The future of stem curriculum and instructional design: A research and development agenda for learning designers. *Report of a Workshop Series*. ED535224. Retrieved from: http://www.mathcurriculumcenter.org

Cerf, V. (2012). Emergent properties, human rights, and the Internet. *Internet Computing*, 87-88.

ChanLin, L. J. (2008). Technology integration applied to project-based learning in science. *Innovations in Education and Teaching International*, *45*(1), 55-65. doi:10.1080/14703290701757450

Clark, R. (1983). Reconsidering research on learning from media. *Review of Educational Research*, *53*(4), 445-459. Retrieved from http://rer.sagepub.com/content/53/4/445.short

Clark, R. (1994). Media and method. *Educational Technology Research and Development* 42(3), 7-10. Retrieved from http://www.springerlink.com/index/847312X345GP0374.pdf

Clark, R. E. (2009). Translating research into new instructional technologies for higher education: Rhe active ingredient process. *Journal of Computing in Higher Education, 21*(1), 4-18. doi:10.1007/s12528-009-9013-8

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2013). *Applied multiple regression/correlation anaylsis for the behavioral science*. Routledge.

Cohen, J. D., Smolkin, L., & Bull, G. (2012). Connected classroom-connected books: Introducing the T-Book. *Learning and Leading with Technology*, *39*(5), 28.

Connection. (2015). *Oxford Dictionary Online*. Retrieved from: http://www.oxforddictionaries.com/us/definition/american_english/connection

Cooper, M. M. (1997). Distinguishing critical and post-positivist research. *College Composition and Communication*, *48*(4), 556-561.

Create. (2015). *Oxford Dictionary Online*. Retrieved from: http://www.oxforddictionaries.com/us/definition/american_english/create

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches. London, United Kingdom: SAGE Publications.

Cuban, L. (2001). Oversold and underused: Computers in the classroom. Cambridge, MA: Harvard University Press.

Curriculum. (3rd ed.). (2000). The American heritage college dictionary. Boston: NY.

De Jong, M. T., & Bus, A. G. (2002). Quality of book-reading matters for emergent readers: An experiment with the same book in a regular or electronic format. *Journal of Educational Psychology*, *94*(1), 145-155. doi:10.1037//0022-0663.94.1.145

DeVellis, R.F. (1991). *Scale development*. Newbury Park, NJ: Sage Publications.

Dick, W., Carey, L., Carey, J. (2009). *The systematic design of instruction.* Upper Saddle River, NJ: Pearson.

Digital. (2015). *Oxford Dictionary Online*. Retrieved from www.oxforddictionaries.com/us/definition/american_english/digital

Doty, D., Popplewell, S., & Byers, G. (2001). Interactive CD-ROM storybooks and young readers' reading comprehension. *Journal of Research on Technology in Education, 33*(4), 374-384.

Ducamp, G., & Dejaegher. (2013). Incorporating engineering in middle school science: A pilot study teaching about electricity. *Proceedings of the American Society for Engineering Education, 120th annual Conference & Exposition* (pp. 23.731.1 - 23.731.19). Retrieved from: https://peer.asee.org/19745

Dunn-Rankin, P., Knezek, G., Wallace, S., Zhang, S. (2012). *Scaling methods* (2nd ed.). New York, London: Psychology Press.

Eisenberg, M. (2011). Educational fabrication, in and out of the classroom. In M. Koehler & P. Mishra (Eds.), *Proceedings of the Society for Information Technology & Teacher Education International Conference 2011* (pp. 884-891). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Ejiwale, J. A. (2012). Facilitating teaching and learning across stem fields. *STEM Education: Innovations and Research*, *13*(3), 87-95.

Ertmer, P., & Newby, T. (1993). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, *6*(4), 50-72.

Ertmer, P., & Ottenbreit-Leftwich, A. T. (2010). Teacher Technology change: How Knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*, 255-284. doi:GALE|A221849729

Ertmer, P., & Newby, T. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, *26*(2), 43-71. doi:10.1002/piq

Eshet, Y., & Chajut, E. (2007). Living books: The incidental bonus of playing with multimedia. *Journal of Educational Multimedia and Hypermedia*, *16*, 377-388. Retrieved from http://www.editlib.org/p/21878

Fabrication. (2015). *Oxford Dictionary Online*. Retrieved from http://www.oxforddictionaries.com/us/definition/american_english/fabrication

Field, R. (*n.d.*). John Dewey (1859-1952). *Internet Encyclopedia of Philosophy*. ISSN 2161-0002. Retrieved from http://www.iep.utm.edu/dewey/

Fleming, L. (2013). Expanding learning opportunities with transmedia practices: Inanimate Alice as an exemplar. *Journal of Media Literacy Education*, *5*(2), 370-377.

Fosnot, C. T., & Perry, R. S. (1996). A psychological theory of learning. In C. T. Fosnot (Ed.), Constructivism: A psychological theory of learning. *Constructivism: Theory, perspectives, and practice*, (pp. 8-33). New York: Teachers College Press.

Fox-Turnbull, W., & Snape, P. (2011). Technology teacher education through a constructivist approach. *Design & Technology Education*, *16*(2), 45-57.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (1993). *How to design and evaluate research in education* (Vol. 7). New York, NY: McGraw-Hill.

Gagne, R. Gagne, R. M. (1997). Mastery learning and instructional design. *Performance Improvement Quarterly*, *10*(1), 7–18. doi:10.1111/j.1937-8327.1988.tb00003.x

Gehlhar, K., Wüller, A., Lieverscheidt, H., Fischer, M. R., & Schäfer, T. (2010). Is a PBL curriculum a better nutrient medium for student-generated learning issues than a PBL island? *Advances in Health Sciences Education : Theory and Practice*, *15*(5), 671-83. doi:10.1007/s10459-010-9229-4

Gershenfeld, N. (2005). FAB: The coming revolution on your desktop--From personal computers to personal fabrication. New York, NY: Basic Books.

Goonatilake, R., & Bachnak, R. (2012). Promoting engineering education among high school and middle school students. *Journal of STEM Education: Innovations and Practice, 13*(1), 15-22. Retrieved from http://eric.ed.gov/?id=EJ978717

Gunter, B. (2003). *News and the net.* Mahwah, NJ: Erlbaum.

Hall, C., Dickerson, J., Batts, D., Kauffmann, P., & Bosse, M. (2011). Are we missing opportunities to encourage interest in STEM fields? *Technology Education*, *23*(1), 32-46. Retrieved from http://libproxy.library.unt.edu:2105/PDFS/EJ965337.pdf

Harwell, M., Moreno, M., Phillips, A., Guzey, S. S., Moore, T. J., & Roehrig, G. H. (2015). A study of STEM assessments in engineering, science, and mathematics for elementary and middle school students. School Science & Mathematics, 115(2), 66-74. doi:10.1111/ssm.12105

Hernández-Ramos, P., & De La Paz, S. (2009). Learning history in middle school by designing multimedia in a project-based learning experience. *Journal of Research on Technology Education*, *42*(2), 151-173.

Herschbach, D. (2011). The STEM initiative: Constraints and challenges. Journal of STEM Tech Education. 48(1), 96-123.

Horejsi, M. (2014). Teaching STEM with a 3D printer. *The Science Teacher*, 81(4), 10.

Huitt, W., & Hummel, J. (2003). Piaget's theory of cognitive development. *Educational Psychology Interactive*, 3(2). Retrieved from: http://www.edpsycinteractive.org/topics/cognition/piaget.html

Inanimate Alice (2015). About the project. Retrieved from: http://www.inanimatealice.com/australia/about.html

Ing, M. (2013). Can parents influence children's mathematics achievement and persistence in STEM careers? *Journal of Career Development*, *41*(2), 87-103. doi:10.1177/0894845313481672

Interactive. (2015). *Oxford Dictionary Online*. Retrieved from: http://www.oxforddictionaries.com/us/definition/american_english/interactive

International Reading Association. (2012). Adolescent literacy (Position statement, Rev. 2012 ed.). Newark, DE. Retrieved from: http://www.literacyworldwide.org/docs/default-source/where-we-stand/adolescent-literacy-position-statement.pdf?sfvrsn=8

Intervene. (2015). Merriam-Webster dictionary. Retrieved from: http://www.merriam-webster.com/dictionary/intervene

Intervention. (2000). The American heritage college dictionary.

Jenkins, H. (2007). Transmedia Storytelling 101. Confessions of an Aca-Fan: The Official Weblog of Henry Jenkins [Web log post]. Retrieved from: http://henryjenkins.org/2007/03/transmedia_storytelling_101.html

Jenkins, H. (2010). Transmedia Storytelling and entertainment: An annotated syllabus. *Continuum*, *24*(6), 943-958. doi:10.1080/10304312.2010.510599

Jia, Q. (2010). A brief study on the implication of constructivism teaching theory on classroom teaching reform in basic education. *International Education Studies*, *3*(2), 197–200.

Johnson, C., & Delawsky, S. (2013). Project-based learning and student engagement. *Academic Research International*, *4*(4), 560-571.

Labbo, L. D., & Reinking, D. (1999). Negotiating the multiple realities of technology in literacy research and instruction. *Reading Research Quarterly*, *34*, 478-493. doi:10.1598/RRQ.34.4.5

Killian, J. N. (2011). The teaching/learning of digital natives. *Journal of Music Teacher Education*, *21*(1), 7-10. doi:10.1177/1057083711414393

Kjellstrom, W., Tillman, D., Cohen, J., & Ducamp, G. (2012). Exploring project-based learning and digital fabrication through transmedia books. In P. Resta (Ed.), *Proceedings of the Society for Information Technology & Teacher Education International Conference 2012* (pp. 1041-1045). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Knaepen, K., Goekint, M., Heyman, E. M., & Meeusen, R. (2010). Neuroplasticity--exercise-induced response of peripheral brain-derived neurotrophic factor: a systematic review of experimental studies in human subjects. *Sports Medicine*, *40*(9), 765+. Retrieved from http://go.galegroup.com/ps/i.do?id=GALE%7CA235626740&v=2.1&u=txshracd2679&it=r&p=HRCA&asid=3a6e535768ba22716189f9a46624acdc

Knezevich, S. J., & Eye, G. G. (1970). *Instructional technology and the school administrator*. Washington, DC: American Association of school Administration.

Koehler, M. J., & Mishra, P. (2005). Teachers learning technology by design. *Journal of Computing in Teacher Education*, *21*(3), 94-102.

Koltay, T. (2011). The media and the literacies: Media literacy, information literacy, digital literacy. *Media, Culture & Society*, *33*(2), 211–221. doi:10.1177/0163443710393382

Kozma, R. (1991). Learning with media. *Review of Educational Research*, *61*(2), 179-211. Retrieved from http://rer.sagepub.com/content/61/2/179.short

Kozma, R. (1994a). The influence of media on learning: The debate continues. *School Library Media Research*, *22*(4), 1-13.

Kozma, R. (1994b). Will media influence learning? Reframing the debate. *Educational Technology Research and Development*. 42(2), 7-19. Retrieved from http://link.springer.com/article/10.1007/BF02299087

Kumar, M., & Natarajan, U. (2007). A problem-based learning model: Showcasing an educational paradigm shift. *Curriculum Journal*, *18*(1), 89-102. doi:10.1080/09585170701292216

Kundart, J., Momeni-Moghadam, H., Nguyen, J., & Hayes, J. R. (2012). Comparing binocular vision suppression on an e-reader versus a smartphone. *Journal of Behavioral Optometry, 23*(5/6), 152-155.

Lai, H.-C., Chang, C.-Y., Wen-Shiane, L., Fan, Y.-L., & Wu, Y.-T. (2013). The implementation of mobile learning in outdoor education: Application of QR codes. *British Journal of Educational Technology*, *44*(2), E57–E62. doi:10.1111/j.1467-8535.2012.01343.x

Lamb, A. (2011). Reading Redefined for a Transmedia Universe. *Learning & Leading with Technology*, *39*(3), 12-17.

Lamb, A., & Johnson, L. (2010). Divergent convergence part 2: Teaching and learning in a transmedia world. *Teacher Librarian, 38*(1), 64-69.

Larson, L. C. (2010). Digital readers: The next chapter in e-book reading and response. *The Reading Teacher*, *64*(1), 15-22. doi:10.1598/RT.64.1.2

Lea, S., Stephenson, D., & Troy, J. (2003). Higher education students’ attitudes to student-centered learning: Beyond ‘educational bulimia’?. *Studies in higher education*, 28(3), 321-334. Retrieved from: http://dx.doi.org/10.1080/03075070309293

LeapFrog. (2014). The history of leapfrog. Retrieved from: http://www.leapfrog.com/en-us/about-us/history.html

Lebert, M. (2004). Changing the world through e-books. Paris, France: French by Edition Actu n° 90.

Lee, C., & Kolodner, J. L. (2011). Scaffolding students’ development of creative design skills : A Curriculum Reference Model. *Journal of Educational Technology & Society*, *14*(1), 3-15.

Lefever-Davis, S., & Pearman, C. (2005). Early readers and electronic texts: CD-ROM storybook features that influence reading behaviors. *The Reading Teacher*, *58*(5), 446-454.

Leonard, D. (2002). *Learning theories*: A to Z. Post Road West, Westport: Greenwood Publishing Group, INC.

Lim, P., & Tay, Y. (2003). Information and communication technologies (ICT) in an elementary school: Students' engagement in higher-order thinking. *Journal of Educational Multimedia and Hypermedia*, *12*(4), 425-451.

Liou, P.-Y., Desjardins, C. D., & Lawrenz, F. (2010). Influence of scholarships on STEM teachers: Cluster analysis and characteristics. *School Science and Mathematics*, *110*(3), 128-143.

Locke, E. (2008). Proposed model for a streamlined, cohesive, and optimized K-12 STEM curriculum with a focus on engineering. *Journal of Technology Studies*. 35(2). Retrieved from: http://scholar.lib.vt.edu/ejournals/JOTS/v35/v35n2/locke.html

Mackenzie, G. N., & Bebell, C. (2014). Curriculum development. *Review of Educational Research*, *21*(3), 227-237.

Marcoux, E. (2012). Use technology wisely. *Teacher Librarian*, *40*(1), 61 – 63.

Masek, A., & Yamin, S. (2010). Problem-based learning model: A collection from the literature. *Asian Social Science*, *6*(8), 148-157.

Matthew, K. I. (1996). The impact of CD-ROM storybooks on children's reading comprehension and reading attitude. Journal of Educational Multimedia and Hypermedia, 5(3/4), 379-394.

Matthew, K. I. (1997). A comparison of the influence of interactive CD-ROM storybooks and traditional print storybooks on reading comprehension. *Journal of Research on Computing in Education*, *29*(3), 263-275

Maynard, S. (2010). The impact of e-books on young children's reading habits. *Publishing Research Quarterly*, *26*(4), 236-248. doi:10.1007/s12109-010-9180-5

McCoach, D. B., & Siegle, D. (2003). The School Attitude Assessment Survey-Revised: A new instrument to identify academically able students who underachieve. *Educational and Psychological Measurement*, *63*(3), 414-429. doi:10.1177/0013164402251057

McKenney, S., & Voogt, J. (2012). Teacher design of technology for emergent literacy: An explorative feasibility study. *Australasian Journal of Early Childhood*, 37(1), 4-12.

McMillen, L., Shanahan, S., Macphee, J., & Hester, J. (1997). Materials that make the mark integrating technology in the classroom. *Language Arts*, *74*(2), 137-149.

McPherson, S. (2011). President's message: The buzz at the 2011 National Technology Leadership Summit. *Journal of Digital Learning in Teacher Education*, *28*(2), 52.

Media. (2015). *Oxford Dictionary Online*. Retrieved from http://www.oxforddictionaries.com/us/definition/american_english/media

Medium. (2015). *Oxford Dictionary Online*. Retrieved from http://www.oxforddictionaries.com/us/definition/american_english/medium

Mills, N. (2009). A "guide du routard" simulation: Increasing self-efficacy in the standards through project-based learning. Foreign Language Annals, 42(4), 607-639. Retrieved from http://search.ebscohost.com/

Milosavljevic, M., & Oberlander, J. (1998). Dynamic hypertext catalogues: Helping users to help themselves. In *Proceedings of the ninth ACM conference on Hypertext and hypermedia:*

links, objects, time and space---structure in hypermedia systems: links, objects, time and space---structure in hypermedia systems (pp. 123-131). ACM.

Mingfong, J., Yam San, C., & Ek Ming, T. (2010). Unpacking the design process in design-based research: *Proceedings of the 9th International Conference of the Learning Sciences - Volume 2*. (pp. 470-471). Location: Chicago.

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *The Teachers College Record*, *108*(6), 1017-1054.

Model. (2015). *Oxford Dictionary Online*. Retrieved from http://www.oxforddictionaries.com/us/definition/american_english/model

Moos, D. C., & Marroquin, E. (2010). Multimedia, hypermedia, and hypertext: Motivation considered and reconsidered. *Computers in Human Behavior*, 26(3), 265-276. doi:10.1016/j.chb.2009.11.004

National Telecommunications and Information Administration, (1998). Falling through the NET II: New data on the digital divide. Retrieved from http://www.ntia.doc.gov/files/ntia/publications/falling-through-net-ii.pdf

New York City Department of Education. (2009). Project-based learning: Inspiring middle school students to engage in deep and active learning. New York, NY: New York City Department of Education.

Newcombe, N. S. (2010). Picture this: Increasing math and science learning by improving spatial thinking. *American Educator*, 34(2), 29-43.

Noddings, N. (2012). Philosophy of education. Westview press. Boulder, CO.

Norris, C., & Soloway, E. (2015). The 11 barriers to technology adoption. *The Journal*. Retrieved from http://thejournal.com/Articles/2015/02/23/The-11-Barriers-to-Technology-Adoption.aspx?Page=1

Oakley, G., & Jay, J. (2008). “Making time” for reading: Factors that influence the success of multimedia reading in the home. *The Reading Teacher*, *62*(3), 246-255. doi:10.1598/RT.62.3.6

Parker, J., & McDonald, R. (2014). Stories are more than paper: Using transmedia with young adults. *Proceedings of International Federation of Library Associations World Library and Information Congress 2014 – Lyon - Libraries, Citizens, Societies: Confluence for Knowledge*. (pp. 16-22). Location: Lyon, France. Retrieved from http://library.ifla.org/id/eprint/882

Parsad. B., & Lewis L. (2003). Remedial education at degree-granting postsecondary institutions in fall 2000. NCES 2004-010. Washington, DC: United States Department of Education, National Center for Education Statistics.

Phipps, L. J., & Evans, R. N. (1968). Curriculum development. *Review of Educational Research*, *38*(4), 367-381.

Prensky, M. (2001). Digital natives, digital immigrants Part 1. *On the Horizon*, *9*(5), 1-6. doi:10.1108/10748120110424816

Priestley, M. (2010). Schools, teachers, and curriculum change: A balancing act? *Journal of Educational Change*, *12*(1), 1-23. doi:10.1007/s10833-010-9140-z

Provasnik, S., Kastberg, D., Ferraro, D., Lemanski, N., Roey, S., & Jenkins, F. (2012). Highlights from TIMSS 2011: Mathematics and science achievement of United States fourth- and eighth-grade students in an international context. Retrieved from: https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2013009

Pullinger, K., Havard, A., & Hundley, M. (2013). Digital Storyworlds: Transmedia literature in the ELA classroom. *Language Arts*, *91*(2), 126-131.

Quintanilla, B., Stansell, A., Tyler-Wood, T., & Zimmerman, E. (2013). Engineers needed: Help Tamika save the farm. In M. Searson & M. Ochoa (Eds.), Proceedings of the Society for Information Technology & Teacher Education International Conference 2014 (Vol. 2014, No. 1, pp. 1310-1312). Location: Savannah, GA.

Raybourn, E. (2014). A new paradigm for serious games: Transmedia learning for more effective training and education. *Journal of Computational Science*, 5(3), 471-481. doi:10.1016/j.jocs.2013.08.005

Reading. (2000). The American heritage college dictionary (3rd ed.).

Roblyer, M. D., & Knezek, G. A. (2003). New millennium research for educational technology: A call for a national research agenda. *Journal of Research on Technology in Education, 36*(1), 60-71.

Roblyer, M. & Doering, A. (2006). Integrating educational technology into teaching (4th ed.). Upper Saddle River, New Jersey: Pearson Education Inc.

Sadik, A. (2008). Digital storytelling: A meaningful technology-integrated approach for engaged student learning. *Educational Technology Research and Development*, 56(4), 487-506. doi:10.1007/s11423-008-9091-8

Saettler, P. (1990). *The evolution of American educational technology*. Englewood, Colorado: Libraries Unlimted, Inc.

Salkind, N. J. (2004). *Statistics for people who (think they) hate statistics* (3rd ed.). Thousand Oaks, CA: Sage.

Schuster, D., Buckwalter, J., & Marrs, K. (2012). Aligning university-based teacher preparation and new STEM teacher support. *Science Educator*, *21*, 39-44. Retrieved from http://www.eric.ed.gov/ERICWebPortal/recordDetail?accno=EJ997505

Schwalm, J., & Tylek, K. (2012). System wide implementation of project-based learning: The Philadelphia approach. *Afterschool Matters, Spring*(15), 8. Retrieved from http://www.eric.ed.gov/ERICWebPortal/recordDetail?accno=EJ980187

Segal-Drori, O., Korat, O., Shamir, A., & Klein, P. S. (2009). Reading electronic and printed books with and without adult instruction: Effects on emergent reading. *Reading and Writing*, *23*(8), 913–930. doi:10.1007/s11145-009-9182-x

Self. (2015). *Oxford Dictionary Online*. Retrieved from http://www.oxforddictionaries.com/us/definition/american_english/self

Shamir, A., & Korat, O. (2006). How to select CD-ROM storybooks for young children: The teacher's role. *The Reading Teacher, 59*(6), 532-543. doi:10.1598/RT.59.6.3

Shay, S. (2008). Beyond social constructivist perspectives on assessment: The centring of knowledge. *Teaching in Higher Education*, *13*(5), 595-605. doi:10.1080/13562510802334970

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.

Smith, S., Tillman, D., Mishra, P., Slykhuis, D., Alexander, C., Henriksen, D., Goodman, A. (2014). In M. Searson & M. Ochoa (Eds.), Building multidisciplinary connections: Intersections of content, creativity, and digital fabrication technologies: *Proceedings of* *the Society for Information Technology & Teacher Education International Conference 2014* (pp. 2506-2510). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Sparks, D., & Malkus, N. (2013). Statistics in brief: First-year undergraduate remedial coursetaking: 1999-2000, 2003-04, 2007-08. National Center for Education Statistics, (January, 2013).

Stansell, A. (2014). Media Evolution. In *World Conference on Educational Multimedia, Hypermedia , and Telecommunications* (Vol. 2014, No. 1, pp. 2523-2526).

Stansell, A, Quintanilla, B. U., Zimmerman, E., & Tyler-Wood, T. (2015). Teaching engineering concepts through a middle school transmedia book. *TechTrends*, *59*(2), 27-31.

Sternberg, R., Sternberg, K. (2011). *Cognitive psychology*. Boston, MA: Cengage Learning.

Suldo, S. M., Shaffer, E. J., & Shaunessy, E. (2007). An independent investigation of the validity of the School Attitude Assessment Survey--Revised. *Journal of Psychoeducational Assessment*, *26*, 69-82. doi:10.1177/0734282907303089

Taylor, R. H., & Bluemel, N. L. (2003). Pop-up books: An introductory guide. *Collection Building*, *22*(1), 21-32. Retrieved from http://search.proquest.com/docview/219874952?accoutnid=7113

The White House Press Release. (2013). President Obama launches “Educate to Innovate” campaign for excellence in science, technology, engineering & math (stem) education [Press release]. Retrieved from http://www.whitehouse.gov/the-press-office/president-obama-launches-educate-innovate-campaign-excellence-science-technology-en

Three-dimensional. (2015). Merriam-Webster dictionary. Retrieved from: http://www.merriam-webster.com/dictionary/three-dimensional

Tseng, K.-H., Chang, C.-C., Lou, S.-J., & Chen, W.-P. (2011). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, *23*(1), 87-102. doi:10.1007/s10798-011-9160-x

Two-dimensional. (2015). Merriam-Webster dictionary. Retrieved from: http://www.merriam-webster.com/dictionary/two-dimensional

Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). Instruments for Assessing Interest in STEM Content and Careers. *Journal of Technology and Teacher Education*, *18(2)*, 341-363.

U.S. Department of Commerce. (1999). Falling through the NET. Defining the digital divide. A report on the telecommunications and information technology gap in America. *Journal of Government Information*, *27*, 245-246). doi: 10.1016/S1352-0237(00)00138-6

U.S. Department of Education, National Center for Educational Statistics. (1995). *Pursuing excellence: A study of United States fourth-grade mathematics and science achievement in international context*. Retrieved from http://nces.ed.gov/pubs97/97255.pdf

U.S. Department of Education, National Center for Education Statistics. (1996). *Pursuing excellence: A study of United States eighth-grade mathematics and science teaching, learning, curriculum, and achievement in international context: Initial findings from the Third International Mathematics and Science Study*. NCES 97-198. Retrieved from http://nces.ed.gov/pubs97/97198.pdf

U.S. Department of Education, Center for Educational Statistics. (2000). *Highlights from TIMMS 1999 results.* Retrieved from: http://nces.ed.gov/pubs2001/2001027.pdf

U.S. Department of Education. Institute of Educational Sciences. *(n.d.)* National Center for Educational Statistics. Trends in International Mathematics and Science Study (TIMMS) overview. Retrieved from https://nces.ed.gov/TIMSS/

U.S. Department of Education, Institute of Educational Sciences. (2003a). Center for Educational Statistics. *Highlights from the trends in international mathematics and science study (TIMSS)*. Retrieved from: https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2005005

U.S. Department of Education, Institute of Educational Sciences, (2003b). National Center for Education Evaluation and Regional Assistance. *Identifying and implementing educational practices supported by rigorous evidence: A user friendly guide*. Retrieved from: http://ies.ed.gov/ncee/pubs/evidence_based/randomized.asp

U.S. Department of Education, Office of Educational Technology. (2010). *National Education Technology Plan*. Retrieved from http://tech.ed.gov/wp-content/uploads/2013/10/netp2010.pdf

U.S. Department of Education, Office of Innovation and Improvement. (2014). *Why use transmedia in early learning?* Retrieved from http://www.ed.gov/edblogs/oii/2011/04/why-use-transmedia-in-early-learning/

Van Dijk, J. A. (2006). Digital divide research, achievements and shortcomings. *Poetics*, *34*(4), 221-235.

Vander Ark, T. (2013). The future of learning: Personalized, adaptive, and competency-based. DreamBox Learning. Retrieved from: http://www.dreambox.com/white-papers/the-future-of-learning

Vaughn, T. (2011). *Multimedia: Making it work* (8th ed.). New York: NY: McGraw-Hill.

Wadmany, R., & Kliachko, S. (2014). The significance of digital pedagogy: Teachers' perceptions and the factors influencing their abilities as digital pedagogues. *I-Manager's Journal of Educational Technology*, *11*(3), 22-34.

Who we are. (2015). *Qualtrics*. Retrieved from: http://www.qualtrics.com/about/

Williams, T., Levine, D., Jocelyn, L., Butler, P., Haynes, J., & Heid, C. (2000). Mathematics and Science in the Eighth Grade: Findings from the Third International Mathematics and Science Study. Education Statistics Quarterly, 2(4), 63-69. Retrieved from: http://nces.ed.gov/pubs2000/2000014.pdf

Williams, J. (2011). STEM education: Proceed with caution. *Design and Technology Education: An International Journal*, *16*(1), 26-36. Retrieved from https://jil.lboro.ac.uk/ojs/index.php/DATE/article/view/1590

Williams, T., Kirst, M. W., & Haertel, E. (2010). Gaining ground in the middle grades: Why some schools do better. *Mountain View, CA*: EdSource. Retrieved from www.eddigest.com

Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2009). *Highlights from TIMSS 2007: Mathematics and science achievement of US fourth-and eighth-grade students in an international context*. National Center for Education Statistics, Institute of Education

Sciences, US Department of Education. Retrieved from: https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2009001