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Effect of Chemoscan Creation on High School Students' Attitudes Toward Science

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Abstract

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MS, Walden University, 2010

BS, University of South Carolina, 1993

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Whether the activity of creating digital art influences high school students' attitudes toward science is unknown. The purpose of this study was to determine if the creation of artistic digital chemoscans by high school students influences their attitudes toward science. In this study, ninth grade high school students' attitudes toward science were examined after participating in the creation of chemoscans in their science classroom. The theory of affective domain helped explain the process that leads to a person's behavior toward a certain phenomenon in the educational setting. The research questions concerned the use of chemoscan creation in the physical science classroom and if and whether implementation effected a change in students' attitudes toward science. Archival pre- and posttest data from the Test of Science Related Attitude was used to measure high school students' attitudes toward science in 7 categories. Archived student pre- and posttest data were treated with multiple regression for analysis. Key findings of this study showed that creation of artistic digital chemoscans (a) impacted one of the seven subscales of science attitude from the Test of Science related Attitude entitled attitude toward the normality of scientists, (b) did not have an impact on the any of the other six subscales from the TOSRA and (c) was influenced by teacher effect. This study may contribute to social change by providing improved training for science teachers who implement digital art activities, which may lead to some students enjoying science more and then possibly going into science careers.

Effect of Chemoscan Creation on High School Students' Attitudes in Science

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Dedication

I would like to take this opportunity to honor the people that helped make this work possible. First, I would like to thank my mother who has been supporting me through the entire writing process and who has been my greatest cheerleader. This research would not have been possible without the inspiration and support of Dr. Edward Lilley whose beautiful photography inspired the chemoscan process and helped me begin the journey of sharing art with my students in the classroom. I would also like to thank my sister, Myra, for always being there for me and knowing I was going to finish this thing eventually. I cannot forget to include my three wonderful daughters, Amanda, Alexis, and Autumn, who put up with my frustration and constant editing sometimes giving up things they wanted to do to help me.

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Chapter 1: Introduction to the Study

Introduction

The purpose of this naturalistic, quasi-experimental study was to determine if student creation of artistic digital chemoscans by high school students influences their attitudes toward science. Researchers have examined the use of art in regular classroom teaching to increase critical thinking skills; however, few studies have focused on the use of creative digital artistic images in the science classroom to create a more positive attitude toward science (Alessandri, Vecchione, & Caprara, 2015). Negative attitudes toward science have been documented in elementary students, and some researchers have found these attitudes continue through to high school (Chachashvili-Bolotin, Milner-Bolotin, & Lissitsa, 2016; Christensen & Knezek, 2017; Cox, Masnick, Osman, & Valenti, 2016; Hasni & Potvin, 2014; Hasni, Potvin, & Sy, 2017). Possessing a poor attitude toward science has been found by some researchers to lead to a decline in the number of students choosing science-related courses and, therefore, careers (Deemer, Smith, Thoman, & Chase, 2014; Hasni et al., 2017; Jones, McDermott, Tyrer, & Zanker, 2018). One way to address the negative attitudes toward science may be to encouage activities combining technology and art; however, little research has been done in this area. The findings of the study may have implications for positive social change because science teachers can use them to learn how technology and art might be used to improve students' attitudes.

Chapter 1 includes background on the study topic. Next, the problem and purpose statements are provided followed by a presentation of the research questions (RQ) and corresponding hypotheses of the study are presented. I also discuss the relationship between the theoretical base and the creation of the study instrument as well as how the propositions of the affective domain informed this study. Chapter 1 also includes a description of the nature of the study, important definitions and assumptions related to the study, as well as a description of the scope and limitations of the study. The chapter ends with a description of the significance of the study.

Background

The research literature related to the scope of the study topic includes how technology in the classroom can enhance the student experience. Technology has become infused into all parts of modern society, and educators are looking for methods that use this technology to allow students to create, connect with others, and contribute to the world around them. Combining technology and art to create beautiful, artistic visualizations of scientific concepts is one way teachers are trying to make learning more engaging (Sousa & Pilecki, 2013). Other methods include digital storytelling (Liao, Motter, & Patton, 2016), game design (Jenson & Droumeva, 2016), movie making (Liao et al., 2016), and virtual reality software (Herga, Grmek, & Dinevski, 2014), which allow students to use artistic design capabilities while learning scientific processes. The application of technology has become an important component for helping students acquire 21st century learning skills, including critical thinking, problem solving, communication, collaboration, creativity, and digital literacy (Liao et al., 2016; Partnership for 21st Century Skills, 2016). This idea applies to the science teacher and the use of technology to focus students on their creative abilities while learning science concepts. Using technology can be an important method for teachers to encourage students to appreciate the connection between creativity, art, science, and technology. Both the International Society of Technology in Education (ISTE) and Next Generation Science Standards (NGSS) provide frameworks for student standards that suggest learning digital skills can transform their education (ISTE, 2018; NGSS, 2019). Using technology and art to engage students in learning can lead students to finding more value in their work and increasing cognitive abilities (Ing, Aschbacher, & Tsai, 2014; Sousa & Pilecki, 2013). The goal of science, technology, engineering, arts, and math (STEAM) based education is to increase student interest in learning about science, which in turn, could lead to an increase in interest in science, technology, engineering, and math (STEM) careers (Land, 2013). Calvert and Schyfter (2017) studied scientists as they worked to develop new technologies and found that when the scientists collaborated with artists, the results often created new dialogues and "what if" scenarios compared to the scientists that did not work with the artists. As Calvert and Schyfter (2017) argued, adding an artistic component to the technology design process could lead to more innovative thinking and discussions as well as better final products.

This study was needed to help determine if digital artistic activities can influence students' attitudes toward science. Learning more about the intersection of educational technology, science, and art is a unique approach that has not been previously studied with high school students. Teachers looking for new and innovative methods to incorporate technology into the classroom to improve students' attitudes might benefit from the results of this study.

Problem Statement

Declining attitudes toward science have been documented to begin as a student gets into higher elementary grades (Hasni & Potvin, 2014; Hasni et al., 2017) and continue into the middle school level (Christensen & Knezek, 2017; Cox et al., 2016) and the high school level (Chachashvili-Bolotin et al., 2016). These poor attitudes toward science have been found to lead to a decline in the number of students choosing science-related courses and, therefore, careers (Christensen & Knezek, 2017; Deemer et al., 2014; Hasni et al., 2017; Jones et al., 2018). According to Krapp and Prenzel (2011), the problem of student interest in STEM could depend on the type of activities and the quality of the instruction. The U.S. Department of Labor, Bureau of Labor Statistics (2015) and the National Academy of Science (2007), all of the top fastest growing careers in America are STEM related, but the United States does not have a sufficient number of students interested in following STEM careers (Belser, Prescod, Daire, Dagley, & Young, 2017). The United States simply does not have enough people with the type of training necessary to fill the open STEM vacancies. In 2016, there were almost 3 million STEM-related vacancies that could potentially not be filled due to lack of training (Pew Research Center, 2014). However, the AmGen Foundation (2016) found that it is not science kids dislike but science classes.

One way this problem has been addressed was by leaders encouraging teachers to use technology in science class in innovative ways. For example, there is much research on how the flipped model of learning encourages the development of 21st century skills, such as digital literacy, critical thinking, creativity, communication, and collaboration

(Roehl, Reddy, & Shannon, 2013). Activities that support adaptability to new technologies are crucial for graduating students to succeed in the workplace. Additionally, educational technology has been used to enhance interest in STEAM as Connor, Karmokar and Whittington (2015) demonstrated that completing activities of design, engineering, and technology considered to have a liberal arts learning, such as studio-based learning, helped students overcome their reluctance to participate in multidisciplinary learning.

Implementing creative and artistic elements using three-dimensional (3D) printing has also been shown to have a positive effect on middle and high school student interest in STEM careers (Bicer, Nite, Capraro, Barroso, & Lee, 2017). The recent push to add art to STEM, making it STEAM, is another way the problem of poor attitudes toward science has been addressed. Many initiatives that have started in the last decade that include liberal and creative arts in the high school science classroom do so with the desire to increase the number of creative thinkers who go into science (Sochacka, Guyotte, & Walther, 2016). Although there is research discussing the combination of visual arts projects as part of science learning, the gap in knowledge was that little research has been done to show how the intersection of technology and the creation of artistic digital images impacts high school students' attitudes toward learning science. Whether the activity of creating digital art influences high school students' attitudes toward science is unknown. The results of this study could help with understanding why many high school students do not have a positive attitude toward learning science.

Purpose of the Study

The purpose of this naturalistic, quasi-experimental study was to determine if the high school student creation of artistic digital chemoscans influences their attitudes toward science. In this study, I examined if the independent variable of chemoscan creation impacts a change in attitude as measured by the dependent variable, the scores on the Test of Science Related Attitude (TOSRA). If artisitic endeavors, like chemoscans, are found to have a positive effect on students' attitudes toward science, it may develop into support for an expanded curriculum that includes art in the STEM or STEAM programs (see U.S. Department of Education & American Institutes for Research, 2016).

Research Questions and Hypotheses

RQ1: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the social implications of science.

RQ 2: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the normality of scientists.

RQ3: The creation of chemoscans in the physical science classroom will improve students' attitudes toward a career interest in science.

RQ 4: The creation of chemoscans in the physical science classroom will improve students' attitudes toward scientific inquiry.

RQ 5: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the adoption of scientific attitudes.

RQ 6: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the enjoyment of science lessons.

RQ 7: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the leisure interest in science.

Null Hypothesis (H_01_0): Students' attitudes toward science are not affected by the creation of chemoscans.

Alternative Hypothesis 1 (H_11_1): Students' attitudes toward science will be affected by the creation of chemoscans.

Alternative Hypothesis 2 (H_01_2): Students' attitudes toward science are affected by the creation of chemoscans when considering teacher effect.

Theoretical Framework

The theoretical base for this study was Krathwohl, Bloom, and Masia's (1964) theory of the affective domain. This theory was developed to help explain the process that leads to a person's behavior toward certain phenomenon in the educational setting (Krathwohl et al., 1964). The affective domain theory is a component of earlier work by Bloom, Englebert, Furst, Hill, and Krathwohl (1956), which includes cognitive and psychomotor domains in addition to the affective domain. All three domains were created to help develop a framework for teacher assessment of learning (Bloom et al., 1956). In this study, I focused solely on the affective domain and its five propositions concerning student's behavior toward science: attending, responding, valuing, organizing, and characterization of a value. Krathwohl et al. asserted that the affective domain included conditions that students are often unaware of, such as their interest level, attitudes, appreciations, values, and emotional sets or biases that are not usually measured. I will describe these propositions in detail in Chapter 2 along with the use of affective domain to support the making of chemoscans as a means of improving student attitudes. The affective domain framework supports the independent variable of increasing student interest in learning science because it characterizes unconscious student conditions, such as emotion, creativity, and acceptance (see Krathwohl et al., 1964). Tiernan and Murray (2018) found that there is a difference in students' attitudes toward learning when given activities that support participation, student engagement, and affective domain unconscious conditions. Ramma, Bholoa, Watts, and Nadal (2018) found that students show more positive attitude toward creative learning when involving affective domain conditions. These findings suggest that teachers could offer activities that enhance a student's attitude toward learning science by using those factors encompassed in the affective domain framework (Ramma et al., 2018).

I used the TOSRA to measure student science attitudes in this study. This instrument was chosen because it has roots in the affective domain theory. Fraser (1981) developed the instrument to gather data on student affective attitudes toward science. The TOSRA was based on Klopfer's (1971) scale, the Structure for the Affective Domain, in relation to science education, which in turn, was based on the structure on Krathwohl et al.'s (1964) affective domain. In Chapter 2, I will further describe the relationship between affective domain and the creation of the TOSRA. How the use of the affective domain as the theoretical framework for this study supports the independent variable as a method for improving students' attitudes toward science will also be described in Chapter 2.

The affective domain theory and the TOSRA instrument supported the quasi-experimental approach used in this study and provided a reliable method to answer the research questions. In this quantitative study, I examined if the creation of digital art during the learning process can influence students' affective attitudes toward science. Therefore, the affective domain and its propositions aligned to the instrument and provided a quantitative way to test the hypotheses to see whether students are affectively influenced by the introduction of the digital art experience in science class. Chapter 2 will include a more thorough explanation of the alignment of the affective domain theory, the TOSRA, and the purpose of the study.

Nature of the Study

For this study, I used a naturalistic, quasi-experimental, quantitative design. In this study, I related the making of chemoscans (i.e., the independent variable) to changes between pre- and posttest scores on the TOSRA (i.e., the dependent variable), controlling for only those students that had made chemoscans in the ninth-grade physical science classroom. I used archival data from pre- and posttests related to scientific attitudes completed by ninth-grade students in high school physical science classes. A quasi-experimental study is a study used to determine the effect of the independent variable without the benefit of random assignment (Creswell, 2014). This research study used human participants and interactions between participants could affect the outcome of this research study, as such, care needed to be taken to minimize threats to internal validity

(Kara & Bakirci, 2018). The district involved in the study had half of the ninth-grade physical science teachers implement six chemoscan digital activities during a 9-week study period. The comparison group was ninth-grade physical science students who were similar in student profile and physical science class level but who did not participate in chemoscans activities until after the posttest.

A chemoscan is a digitized image that comes as a result of of the reaction two or more chemicals in a petri dish placed on a digital scanner and photographed as the reaction occurs (Ezell & Case, 2017). Students chose a chemical reaction they want to image. They put the chemicals chosen into a petri dish and scanned it on a digital scanner. The image was put into a digital editor and edited to the specifications of the student. Students edited the images in a free online photo editor or Photoshop. This process occurred six times throughout the grading period. The chemoscans were displayed in school and community art shows.

Teachers in the district were trained in how to implement the chemoscan lesson. Training for teachers lasted about 1 hour. All teachers involved with the research participants were trained in the chemoscan process to ensure fidelity. The training occurred during the teachers' workday. The teachers were provided with complete instructions concerning chemoscan creation lesson (see Appendix A). The teachers were trained to first demonstrated the chemoscan process before students began their own creations. If for some reason a teacher was unable to understand the process or did not want to participate, there was a substitute teachers available that had been trained to take over the chemoscan creation. I observed the process each time they completed the chemoscan process but did not interact with the teachers or students.

The setting for this study was a rural high school with about 700 students in Grades 9–12. The sampling procedure was a nonprobability, convenience sample. Four physical science classes were used, which included four different teachers. The activity took place over a 9-week grading period with a chemoscan being made once a week.

Definitions

Chemoscan: The independent variable of this study. A research-based, digitized image of a chemical reaction (Ezell & Case, 2017). The chemoscan is a digital image of a chemical reaction as it occurs. Students will choose a chemical reaction they want to image and put the chemicals chosen into a petri dish and scan on a digital scanner. The image will be put into a digital editor and edited to the specifications of the student.

Test of Science Related Attitude (TOSRA): The pre- and posttest scores from this test were the dependent variable of this study. This test was used to measure students' attitudes toward science in seven categories: Social Implications of Science, Normality of Scientists, Attitude toward Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science (see Fraser, 1981).

Assumptions

There were a number of assumptions I had to make in this study. I assumed that students have varying attitudes concerning science, which were measured by the pretest score on the TOSRA. I also assumed that the students answered the TOSRA truthfully.

To address this assumption, the pre- and posttests were anonymous and confidential. These assumptions were checked using the regression model.

The activity took place over a 9-week period with six chemoscans being made. Nine weeks is the typical grading period at the research partner school. An important assumption was that the length of time students participated in making chemoscans was long enough to have an effect. Another assumption was that making six chemoscans would be a high enough number of times to cause a change in attitude.

I also assumed that the research was implemented with fidelity. The standard protocols developed for this activity required that the students participate in six chemoscan developments during the physical science class. I cannot be sure about the conclusions reached when studying the behavior and actions of humans but can acknowledge that the research will be conducted using careful observation and a valid measuring instrument (see Fraser, 1981). The use of numeric measures to measure the students' attitudes toward science was central to this study (see Lovelace & Brickman, 2013). The participants in the comparison and experimental groups had received the same basic science education as most ninth graders in the United States and possessed the same background in science from kindergarten through eighth grade.

Scope and Delimitations

This study was delimited to four classes of ninth grade high school students. The setting was a high school in a rural area. All classes were mixed gender. The groups that made chemoscans and the comparison groups were tested before and after the activity.

The results of this study may not be applicable to students in other grade levels, other science courses, or in other areas of the United States or in other countries.

To maintain external validity, it was necessary to limit the amount of time between the pre- and posttest It was also important to prevent selection bias as much as possible. Selection bias can cause the conclusions drawn from a set of data to be wrong because the data set is different from the population being studied. This externl validity threat was lessened by the inclusion of all physical science classes in the test school. The participants in the study created chemoscans as part of the physical science curriculum; students are placed into the classes by the school district across a similar range of general characteristics.

To maintain internal validity, it was necessary to watch from multiple observation points to maintain consistency. The testing procedures were maintained by the school district implementing the study, which included the instruments, the instrument application, and the administrators of the instrument. The fact that the students could talk to each other during the school day might have caused an internal validity threat. This means that the students made chemoscans but were not be able to see each others' work until after the posttest to prevent discussion and comparison. The pre- and posttest design can cause a threat to internal validity by allowing the participant to have to much knowledge of the upcoming research (Creswell, 2014). I maintained internal validity in this study through the use of the comparison group.

I conducted this study in a rural high school in a context which may not provide generalizable results to students in suburban and urban populations. The participants in this activity were 80% White and not representative of a more ethnically diverse population. Participants were limited to ninth grade students; therefore, the results may be limited in their applicability to students in other grades. To provide as much generizability as possible, all four classes of physical science students in the ninth grade were included.

Limitations

Some restrictions exist when analyzing the resulting data from a study and often account for research variances. Individual confounders affect the results of the survey but are not included in the study design (Creswell, 2014). Perfectly controlled conditions are difficult to maintain in a school setting, and some factors are more obvious than others. The time of day can affect how a student responds to a survey. The fact that students had different teachers limited the ability to determine if Chemoscans or teacher affect caused any change in student attitude.

Lack of diversity in the student population is a limitation. The district where the research took place is 72% White, 18% Black, 6% Hispanic, and 4% other. Another limitation was related to the population chosen to participate in the study. The participants were not selected randomly because they were put into physical science unclasses by the school disrict. This lack of randomization also meant that the hypothesis cannot be tested using a double blind investigation, which helps alleviate possible bias in research results. The fact that students could communicate with each other outside of the research period is a limitation.

There were also a number of potential biases that could have influenced the outcomes of the study. It was necessary to assure proper execution of the study to prevent biased results. Students made their chemoscan on an individual basis to prevent student comments from biasing the resultant feelings the students had as they created the images. There was a specific area set up in the classroom for the creation of the chemoscans during the research period where students could work without interruption from other students. As students created their chemoscans, the classroom teacher was sure not to comment on the student's work to prevent bias. The teacher did discuss how to use the technology but did not comment on the quality or outcome of the chemoscan to prevent bias. There was time during the 9-week testing period for students to to talk to each other about the chemoscan process, but there was no access to the actual chemoscans until the art show.

Significance

One potential contribution of this study could be the advancement of knowledge in the discipline of educational technology related to the how digital art technologies might be used to help improve students' attitudes toward science. The results of the study could advance the teacher practice of using digital art in the science classrooms and inform teachers of innovative practices that might improve students' attitudes toward science. Knowing if and how digital chemoscans influence students' attitudes toward science may help inform teacher practice in how they decide to use digital art methods to link science with the latest technologies. The findings of this study also have potential implications for positive social change. Improved understanding of how technological tools might be used to improve students' attitudes in science could lead to an improved classroom practice, possibly improving student interest in pursuing STEM-based careers in the future.

Summary

In Chapter 1, I described the problem, which was that it was unknown whether the activity of creating digital art influences high school students' attitudes toward science. Helping students learn to like science could lead to more students pursuing STEM-based careers. Innovative and creative thinkers are what the United States is seeking for the future (Belch & Belch, 2013).

In Chapter 2, I will review the need to increase interest in science along with digital technology initiatives being implemented. The chapter included a review of digital technology that has been used in science to change how students learn and visualize science concepts. Information concerning various technology-based teaching methods and the incorporation of digital art into the science classroom will also be provided. Chapter 2 will also include a literature review of current research on technology and art used in science courses. The search parameters used to identify the research will be presented in detail along with an explanation of how articles were chosen.

Chapter 2: Literature Review

Introduction

The problem under study was that it is unknown whether the activity of creating digital art influences high school students' attitudes toward science. While some researchers have explored how to encourage teachers to use technology in science class in innovative ways, their studies have not usually included art. For example, there is much research on how the flipped model of learning encourages the development of 21st century skills, such as digital literacy, critical thinking, creativity, communication, and collaboration (Roehl et al., 2013). Activities that support adaptability to new technologies are crucial for graduating students to succeed in the workplace (Partnership for 21st). Additionally, educational technology has been used to enhance interest in STEAM as Connor et al. (2015) demonstrated by completing activities with students that support the u se of technology to increase positive attitudes toward science. Implementing creative and artistic elements using 3D printing has also been shown to have a positive effect on middle and high school student interest in STEM careers (Bicer et al., 2017). The recent push to add art to STEM, making it STEAM, is another way the problem of poor attitudes toward science have been addressed (Connor, et al., 2015). There is a hope that including liberal and creative arts in the high school science classroom will encourage creative thinkers to go into science (Sochacka et al., 2016). Although some college course projects that combine the creation of visual arts projects as part of science learning have been published (Lima & Timm-Bottos, 2018), little research has been conducted to show how the intersection of technology, creation of artistic digital images, and science impact high school students' attitudes toward learning science. Therefore, the purpose of this naturalistic, quasi-experimental study was to determine if the high school student creation of artistic digital chemoscans influences their attitudes toward science.

In this literature review, I explore the use of digital technology and its use to increase student interest in science. Various types of technology are explored such as the latest technology for modeling scientific concepts in the classroom and citizen science to involve students in real world scientific research. The use of virtual reality and 3D printing is also explored as methods to help increase students' interest in science.

Student engagement with technology, digital art and its relationship to student learning, as well as the importance of creativity in the learning process were the study focus. In this study, I addressed the use of technology in the creation of artistic digital images, entitled chemoscans, in the science classroom that may help students engender a more positive attitude about science. In this chapter, I introduce current research concerning the use of digital art in the science classroom and the role that digital art plays in current initiatives to increase student interest in science, including how digital technology is used to help students visualize science concepts to increase their interest and understanding of complex science models. A gap in the literature exists concerning how student attitudes toward and/or interest in science can be increased using digital art in the teaching of science. Prior to this study, no research concerning the creation of chemoscans in the science classroom had been conducted. Chapter 2 includes background on the theoretical framework of the study. Extant research concerning the need to increase students' interest in science is provided as well as a review of the research concerning initiatives to increase student interest in science. In Chapter 2, I also describe the educational technology used in the science classroom today and how it helps students visualize science concepts. The chapter ends with a discussion concerning science teaching methods and the connection to art.

Literature Search Strategy

To locate sources for this literature review, I used the following databases: Academic Search Complete, Elton B. Stephens Company host, Education Research Complete, Educational Information Center, Google Scholar, Journal Storage, ProQuest, Walden Dissertations, and The World Bank Open Knowledge Repository. The search engines used included Google, Google Scholar, and Bing. I searched for peer-reviewed articles published between 2012 and 2019 to ensure that the most recent and up-to-date research was included in the review of the literature. My use of sources published prior to 2012 was limited only to those with information that was highly relevant to the study. Keyword term and string searches included: *TOSRA, art and science, science interest, digital modeling in the science classroom, 2D modeling in science, 3D modeling in science, virtual reality in the science classroom, virtual reality and science, 3D printing and science teaching, science attitude, science and self-efficacy, Science and TOSRA, benefits of 3D printing in education, benefits of digital technology in the science classroom and teaching, digital storytelling in science, game design in science teaching, STEM, STEAM, STEAM career interest, STEAM to STEM, creativity crisis, science and creativity, hand drawn models for teaching science, digital technology in the science* *classroom, challenges in teaching science, next generation science standards, science attitude, science interest, video making in the science classroom, science videos for teachers, science education, affective domain and science learning,* and *teaching science with technology*.

Theoretical Foundation

The theoretical framework for this study was based on Krathwohl et al.'s (1964) theory of affective domain, first developed to help explain the process that affects a person's behavior toward certain objects or situations for educational purposes. These processes range from simple awareness of an object to the internalization of the object and its effect on a person's behavior (Krathwohl et al., 1964). The affective domain encompasses the behaviors of attitudes of awareness, interest, attention, concern, and responsibility as well as the ability to listen and respond in interactions with others and the ability to demonstrate those attitudinal characteristics or values that are appropriate to the field of study (Krathwohl et al., 1964). The theory of affective domain is deeply rooted in the work of Bloom et al. (1956) and the theoretical propositions of cognitive, affective, and psychomotor domains to explain student behaviors. These domains are considered from an educational viewpoint and were originally developed to help teachers create curriculum and new teaching methods (Bloom et al., 1956). Bloom et al. focused mainly on the cognitive aspect of the propositions from the cognitive domain theory, which come from a place of awareness in action during the learning process. Krathwohl et al. continued Bloom's work with the cognitive domain theory but focused only on the affective domain. Using affective domain taxonomy as the grounding theory of this study, there are five propositions: attending, responding, valuing, organizing, and characterization of a value (Krathwohl et al., 1964). These propositions are those behaviors that students are often unaware of and often not measured (Krathwohl et al., 1964).

Framework Aligned to TOSRA

In this study, I measured students' affective attitudes using an instrument entitled the TOSRA. The TOSRA was developed by Fraser (1981) and was designed to measure seven, distinct, science-related attitudes among secondary school students. These scales, which fall under the affective domain proposition, are: Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. Fraser based the survey on a classification schema designed by Klopfer (1973) entitled, A Structure for the Affective Domain in Relation to Science Education. Klopfer's scale utilized a categorization scheme which

> Was quite unique in that it not only included behaviors pertaining to the student's knowledge, comprehension, and application of science contact, but it also included student behaviors with respect to the processes of scientific inquiry, with respect to an orientation about science's relationships with other aspects of culture, and with respect to attitudes and interests (p. 2).

Fraser used Klopfer's scale to create the TOSRA, a survey which measures a student's change in attitude toward science. Table 1 shows each TOSRA scale and the corresponding constructs with Klopfer's (1971) classification.

Table 1

Name and Classification of Each Subscale in TOSRA Aligned to Klopfer's Classification

TOSRA Scale Name	Klopfer's (1971) Classification
Social implications of Science (S) Normality of Scientists (N)	Manifestation of favorable attitudes towards science and scientists
Attitude to Scientific Inquiry (I)	Acceptance of scientific inquiry as a way of thought
Adoption of Scientific Attitudes (A)	Adoption of 'scientific attitudes'
Enjoyment of Science Lessons I	Enjoyment of science learning experiences
Leisure Interest in Science (L)	Development of interest in science and science related activities
Career Interest in Science I	Development of interest in pursuing a career in science

Note. Reprinted from *TOSRA: Test of science-related attitudes handbook* (1981) by B.J. Fraser Hawthorn, Victoria, Australia: Australian Council for Educational Research. Reprinted with permission of B.J. Fraser.

In development of the TOSRA, Fraser (1981) aimed to create a tool to be used by educators, curriculum designers, and researchers to determine student progress towards certain science attitude goals. Fraser (1981) designed the TOSRA to be useful for educators in the classroom setting for determining the performance of groups or classes of students as they participate in various activities. The test was designed to provide information about attitudes at a particular time or in a pre- and posttest setting (Fraser, 1981). Each scale of the TOSRA includes different components of Krathwohl et al.'s (1964) affective domain proposition using Klopfer's scale as the template.

The first category of the affective domain is *receiving* or *attending*, which refers to the student's willingness to pay attention to an activity or object used during the learning process (Klopfer, 1973). Ideas in this category range from the simple awareness that something exists to particular attention paid on the part of the learner (Karthwohl et al., 1964). The attending category of the Klopfer (1973) scale was entitled Enjoyment of Science Learning Experiences. Fraser (1981) renamed the category, Enjoyment of Science Lessons, on the TOSRA. The TOSRA survey statement terms that align with this category included: follows, gives, listening to discussions of controversial issues with an open mind, and respecting the rights of others (Fraser, 1981).

The third category of the affective domain is called *value* and looks at how the student values the science they are learning (Krathwohl et al., 1964). Value is defined as the idealization of a specific learning skill (Krathwohl et al., 1964). The Klopfer (1973) scale titled this category, Adoption of Scientific Attitudes, and the TOSRA kept the same title (Fraser, 1981). The statements in the TOSRA range from issues concerning the students' desire to improve their cooperative learning skills to their level of commitment to group work and problem solving (Fraser, 1981). Statements on the TOSRA include terms such as *attitude* and *appreciation* (Fraser 1981).

The fourth category of the affective domain is *organization,* which is concerned with identifying different values and determining the conflicts between (Krathwohl, et al., 1964). The Klopfer (1973) scale titled this category, Acceptance of Scientific Inquiry, as a way of thought. The TOSRA used the title, Attitude to Scientific Inquiry (Fraser, 1981). The statements on the TOSRA for this category emphasize comparisons and relationships between science and the student (Fraser, 1981). The statements include terms such as, *adheres to*, *defends*, *identifies*, *relates*, and *realizes* (Fraser, 1981).

The fifth category of the affective domain is *characterization by a value* (Krathwohl et al., 1964). This category looks at the value system of the student and how it may affect their behavior (Krathwohl et al., 1964). This category helps identify preconceived notions students may already have developed about science and their feelings about how science can affect their world (Krathwohl et al., 1964). Klopfer's (1973) scale described this as Manifestation of Favorable Attitudes Towards Science and Scientists. In Fraser's TOSRA (1981), it is broken down into two subscales: Social Implications and Normality of Scientists. The TOSRA statements use terms like *influences*, *acts*, *discriminates*, *revises*, and *verifies*, which help to determine if a student's values concerning science influence their behaviors in different situations (Fraser, 1981).

Justification of Framework

The theory of affective domain was an appropriate choice as the theoretical framework for this study for several reasons. The application of the affective domain theory was justified as it aligned with the purpose of the study. The purpose of this study was to determine if student creation of artistic digital art in high school science classrooms influences the students' attitudes toward science. The author of the TOSRA developed the instrument specifically to help educators and researchers try to determine if changes in students' attitudes toward science had occurred in pre- and posttest classroom settings based on elements of the affective domain (Fraser, 1981). Therefore, the theory and instrument aligned with the purpose of this study.

Next, this theory justifies the studying of affective variables. Krathwohl et al. (1964) intended the development of their work on the affective domain to be used by educators in the creation of new assessments and activities to help teachers in the classroom. Teachers can use data generated from studies such as this to create instructional objectives and activities that are concerned with the students' general patterns of attitude based on affective domain theory.

The affective domain theory is a component of earlier work by Bloom et al. (1956) which includes cognitive and psychomotor domains in addition to the affective domain. It is later work by Krathwohl et al. (1964) on theory of the affective domain that is used as the actual theoretical base. This theory was originally developed to help teachers create educational assessments. All three domains were originally created to help develop a framework for teacher assessment of learning (Bloom et al., 1956). The TOSRA was used to measure student science attitude because it has roots in the affective domain theory. Fraser (1981) developed an instrument to gather data on student affective attitudes toward science. The TOSRA was based on Klopfer's (1971) scale called the Structure for the Affective Domain in relation to science education. Klopfer based the structure on Krathwohl's affective domain theory (Klopfer, 1971). The affective domain theory as the basis for the design of the TOSRA instrument, supports the theoretical base and quasi-experimental approach to provide a reliable method to answer the research questions. The affective domain framework supports the independent variable of increasing student interest in learning.

The use of the affective domain and its five propositions concerning student's behavior toward science is supported with the use of the TOSRA. The statements in the TOSRA are based on the five propositions of attending, responding, valuing, organizing, and characterization of a value. The statements ask students to make judgements concerning their attitude toward various situations in science that can help the evaluator determine the student's attitude. The affective domain framework supports the independent variable of increasing student interest in learning science as it characterizes unconscious student conditions such as emotion, creativity, and acceptance. Krathwohl et al. (1964) asserted that the affective domain included conditions that students are often unaware of including their interest level, attitudes, appreciations, values, and emotional sets or biases.

The affective domain theory helped frame this study for future work by adding to the body of knowledge regarding the use of digital art to impact student affective attitudes about science. Students usually find academic activities meaningful in some way, but trying to find ways to increase positive science attitudes at the same time can be a challenge for any science teacher. The affective domain categories may help educators determine how digital art can be used to promote a science-positive attitude in students. Moreover, this type of research can lead to further understanding about student motivations and behaviors which can assist educators in the design of curriculum which encourages science interest across all grade levels using not only digital art, but other technologies as well.

In this quantitative study, I examined how the creation of digital art during the learning process can influence students' affective attitudes toward science. Therefore, the affective domain and its propositions, aligned to the instrument and provided a quantitative method to test the hypotheses. Buma (2018) found that there is a difference in students' attitudes toward learning when given activities that support participation and student engagement. However, it makes a difference when technology is used as a pedagogical tool for teaching and learning (Westera, 2015) and the teaching value of a tool is reflected in the level of student engagement and the nature of participation garnered (Buma, 2018). Students show more positive attitude toward usefulness of creative learning when involved in affective domain activities. These findings suggest that teachers could offer activities that enhance a student's affective domain to increase motivation and create a more positive attitude toward learning.

This affective domain theory has been applied in previous studies concerning science attitude. Muzyk et al. (2017) used the affective domain proposition to determine the attitudes of pharmacy students which can cause them to harbor discriminatory attitudes towards mental health patients. The researchers used Bloom's affective domain to analyze survey answers from the 65 third-year pharmacy students on the Attribution Questionnaire Short Form. The results were analyzed to determine classroom activities which could help change students' attitudes toward mental health patients in the future. In another study, Ramma et al. (2018) used Bloom's taxonomy of the affective domain to propose a framework of the pedagogical technological integrated medium. This framework would facilitate the use of affective domain practices, such as interest and value, into the integration of technology in a more learner-centered curriculum (Ramma et al., 2018).

The Need to Increase Interest in Science

There is much evidence that there is a need to increase intersest in science in the United States. The National Academy of Science (2007) wrote a report and discussed the poor condition of science and technology in the United States. Science education is crucial for maintaining the technical workforce. President Bush resonated this concern and stressed the need for the United States to increase the number of students in science and engineering fields to continue maintaining current levels of innovation (Gordon, 2007). Over the next 20 years it is expected that STEM based jobs will increase by 17%, while the rate of non-STEM based jobs is only expected to rise about 12% (Change the Equation, 2015; U.S. Department of Education, 2016). STEM workers also will be needed to replace those who are leaving these occupations as the baby boomer generation retires, changes careers, or moves to higher management positions. A lack of new STEM workers would leave the workforce with a great loss of experience that can have long term consequences (Change the Equation, 2015; Jones, 2009). Between 2004 and 2014, employers hired about 2.5 million STEM workers who were entering their occupation for the first time (Change the Equation, 2015). Data from the Department of Labor (2015) demonstrated that employment in occupations related to STEM were projected to grow to more than nine million between 2012 and 2022. The fear that there will not be enough graduates to fill openings in STEM fields has led to an ongoing STEM debate concerning the depth of the problem (Wilson et al., 2012). Research has expressed concerns about the possibility that the United States would become only a consumer of new technology and not a developer (Pew Research Center, 2014).

The need to increase interest in STEM subjects in school has inspired a movement toward the inclusion of art in the teaching of STEM which turns STEM into STEAM. The addition of art is thought to foster creativity in STEM learning, yet it is rarely emphasized in a general classroom. Studies have found that Americans, as a whole, are not as creative as they were in the past (Helding, 2011; Kim, 2011; McLellan & Nicholl, 2013; Ness, 2015). Creative endeavors such as art are usually taught in a separate class; this separation has been proposed as a possibility for the decline in creative thinking among students of all ages (S. Brown, 2015; Kim, 2011). One researcher found creative thinking has been declining over time among Americans of all ages (K. Brown, 2015). Even the advertising industry, which has always been the bulwark of creative thinking, is going through a creativity crisis of its own. The concentration today on “hits” and web site visits, has replaced the idea of garnering people’s interest through creative messaging. The new magnitude of success for advertisers comes in the form of time spent on page and the new metric called dwell which focuses on how long a person stays on a page. This new numbers-based method to determine advertising success has changed the focus from the emotional appeal of a product to a more rational based method of advertising and some researchers feel this has led to a “creativity crisis” that mimics the loss of creativity found in the United States as a whole (Belch & Belch, 2013).

Zhao (2012) examined scores on two tests given world wide to determine if there is a correlation between standardized test scores and creativity. He compared scores on the Programme for International Assessment created by the Organisation for Economic Co-operation and Development, which tests critical thinking skills in math, science, and reading to 15 year olds. The test does not assess the memorization of facts but asks the students to solve real world problems using skills acquired from their education (Organization for Economic Co-operation and Development, 2011). The second test used for comparison in Zhao's study was the was the Global Entrepreneurship Survey , which measures the amount of entrepreneurial action in 65 countries world wide because entrepenuers must use creative skills to create solutions to relevant problems. Zhao (2012) found a negative correlation. The countries that scored the highest on the tended to have lower scores on the Global Entrepreneurship Survey. This suggests that those countries that teach to the test do not support the type of thinking necessary for entrepenurial undertakings (Zhao, 2012).

Kim (2011) used the phrase *creativity crisis* when reporting on the research of Dr. E. Paul Torrance and the Torrance test of creativity over the past 50 years. Research has shown a possible correlation between the creativity crisis and the United States' increasing dependence on data driven teaching causing many teachers to become more and more focused on getting students ready for the test and not on problem solving and critical thinking, which are often described as critical elements of creativity (Helding, 2011; Ness, 2015). McDonald (2017) found that improving students critical thinking skills will help improve entrepreneurial efforts in the future because critical thinking is a key component of the problem-solving process. Focusing primarily on test scores can be shortsighted, and Zhao (2012) found that teaching directly to a test limited the ability of many students to question and solve problems.

One example of this need to bring creative thinking into the workplace is seen in PhD candidate students who require many important skills to succeed in research intensive STEM jobs. Sinche et al. (2017) identified gaps in the training of creative thinking processes for PhD candidates which is a necessary skill when trying to succeed in the world beyond academia, job opportunities for STEM related, research intensive, careers require a change in the teaching and training for PhD candidates that nurtures the creative thinking process. Meyer (2012) found that the inclusion of art in the classroom has been shown to help students become more independent learners and creative thinkers and using art could be the way to challenge the old STEM career view of learning and problem solving for training PhD candidates (Sinche et al., 2017).

One way some educators are trying to renew an interest in STEM courses is to be sure students understand the important role of creativity in the career world. Some have found that introducing art components into science classes provides a great potential for transformative learning (Levick-Parkin, 2014 ; Moller, 2015). Moller (2015) conducted a two-month study of groups of kindergarten children. Three groups played with creative construction toys (LEGO sets, blocks, trains) while three other groups played with social fantasy toys (dolls, teddy bears, dress up clothes). The study looked for the development of children's imagination through the use of transformative play and development of creative thinking. The social-fantasy groups presented a higher mean score than the creative-construction groups when looking at the use of imagination and creative resolutions in play.

Moller (2015) found that communication and the creation of the new situations using imagination fostered the development of transformative and creative activities in children's play. Levick-Parkin (2014) examined art and design education and its ability to have a transformative effect on learning and the possibilities available to apply this to new teaching strategies. The researcher examined the work of various researchers to conclude that transformative education can occur when educational systems apply effective teaching strategies that include art and design practices.

Many educational institutions have kept the lines drawn between subject areas, which can stifle inter-curricular work. The inclusion of art could allow teachers to transform their teaching style in a manner that resonates with improved learning. Students today need to be taught in a way that helps them develop a love for learning that they will bring into the workplace. The inclusion of art in an interdisciplinary teaching situation has been shown to stimulate students' imagination (Charleroy, Frederiksen, Jensen, McKenna, & Thomas, 2012). Art inclusion in the science classroom could foster creative thought and positive expressions toward learning scientific concepts (K. Brown, 2015). Although educators are normally content to place art into a separate classroom, the reality is that art could be a viable method for improving scientific attitude within today's student population (Boden, 2004). Science teachers have been often content to leave creativity to the arts and humanities classes. Teaching for creativity can help students improve critical thinking skills, motivation, and engagement when developing new scientific knowledge (Meyer, 2012; Sri & Binar, 2018).

Initiatives to Increase Student Interest in Science

Currently, in the United States a STEM initiative is needed to support educational curriculum that creates science, technology, engineering, and math activities. STEM curriculum is designed to increase student interest in STEM fields. However, the number of U.S. college students finishing degrees in science, math, and engineering is still decreasing (Defense Advanced Research Projects Agency, 2010). Various studies have highlighted many possible factors contributing to this problem, including student science attitude and interest.

Ness (2015) found that many students do not associate science with creativity. And changing this perception could be the addition of art into the science curriculum or STEAM. She proposes that improving the somewhat stagnant thinking processes in education today by including more creative processes in the learning process can lead to more original thinking and products. Student perception and self-efficacy in mathematics and science is a determining factor in the success of students in STEM based classes (Larson et al., 2015). Researchers in STEM-based curricula have found that the use of more hands on, relevant, cooperative learning methods can increase student interest in science. When students learn using a STEM-supported curriculum, research has suggested that there is an increase in student innovation and critical thinking skills (Conley, McMillan, & Tovar, 2013; Reeve, 2015). STEM program designers want students to become curious about the world around them and to find new and innovative solutions to real world problems. These types of challenges readily lend themselves to piquing the interest of students, which, in turn, can increase a student's interest in the subject matter (Brazell, 2013). The foundation of STEM-based education is to increase student interest in pursuing a future STEM career for more creative teaching methods that incorporate the STEM hands on relevancy is what led to the partner program called STEAM.

The STEAM initiative planners want to increase student's ability to think critically and increase their interest in the STEM-based subjects through the use of interdisciplinary teaching and digital artistic endeavors (Sochacka et al., 2016). This initiative tries to instill enhanced interest in STEM subject matter that is often perceived as difficult (Maltese & Tai, 2010). The STEAM curriculum tries to remove the boundaries between subjects and allows students to make connections between art and science. Various types of art-based information are incorporated into STEAM curriculum, which includes creative and language arts. This also allows students to be more creative and to feel a sense of ownership and pride in their work (Yakman, 2008).

The goal of incorporating art into the STEM curriculum centers on the desire to create critical thinkers and greater interest in learning. The definition for art is broad and it can include dance, music, drawing, writing, and sports. Burgett, Hillyard, Krabill, Leadley, and Rosenberg (2011) suggested that art-integrated learning helps a student develop creativity, problem solving, communication, and critical thinking skills. These skills are considered critical for student success in the 21st century (Partnership for 21st

Century Learning, 2016). The arts have also been found to increase brain development and the growth of neural pathways which can enhance cognitive growth (Sousa & Pilecki, 2013). The arts also help children to understand the world around them and to recognize how they fit into that world.

Jeon and Lee (2014) found that creative ability helped students solve problems by allowing them to make decisions about their own learning and the manner in which it is presented. Their research showed that problem solving abilities increased with the use of creative STEAM-based programs using Sketch 2.0. The researchers did not focus on just the creation of art, but the incorporation of digital artistic works into the regular science curriculum. Some findings suggest that the need to conform begins to change a child's interest in learning about science and disengagement (Patall, Hooper, Vasquez, Pituch, & Steingut, 2018). Patall et al. (2018) believed that children as early as elementary school can become disengaged with science and this problem only gets worse as they get older. This problem can be exacerbated by lessons that do not allow them to be creative and autonomous in their learning. And because many students consider science to be difficult, they think that they will not succeed or often do not try (Patall et al., 2018; Quinn & Lyons, 2011).

Educational Technology Use in Science Courses

Educational technology use in science courses offers students a variety of ways to support the teaching of science. The use of technology is often a critical component of helping students learn 21st-century learning skills, including critical thinking, problem solving, communication, collaboration, creativity, and digital literacy (Liao et al., 2016;

Partnership for 21st Century Skills, 2016). Van Laar, Van Duerson, Van Dijk, and deHann (2017) proposed that digital literacy and the 21st century skills drive the innovation and competition of the modern workforce and are considered vital to student success. In the science classroom, technology skills are an integral part of the science learning process and are incorporated into the NGSS (2019) standards. Science and technology are essentially integrated into the everyday life of modern society. It is necessary for students today to become digital citizens that take responsibility for the use of technology in their personal and professional lives (Crockett, 2018). ISTE (2018) supports the idea that students should build knowledge by using the technology tools that help them develop their ability to think creatively and acquire problem solving skills for the real world. Providing students with the technology to encourage digital literacy in the classroom helps empower their growth towards digital citizenship ISTE (2018). For the science teacher using technology to focus students on their creative abilities while learning science concepts can encourage students to appreciate the connection between creativity, art, and science. Both ISTE (2018) and NGSS (2019) provide a framework for student standards that suggest students learn digital skills that can transform their learning with technology. Educational technology has been used in a variety of ways to support the teaching of science, including augmented and virtual reality citizen science, movie making, gaming, and model creation.

Augmented reality (AR) and virtual reality (VR) technology have been used in a variety of ways to supplement science teaching. The use of educational technology to accomplish modeling and visualization is on the rise spawning new methods for teaching complex science concepts. AR and VR technology can provide teachers and students with the ability to enhance their work with interactive models, images, video and audio which can assist in the transition between the real and virtual world. The use of AR technology such as Google Glass or Microsoft Hololens allow a student to overlay a virtual layer on top of an item they are looking at during the learning process (Hanna et al., 2018; Hantono, Nugroho, & Santosa, 2016). VR technology lets the students be completely immersed in the learning process using OculusRift, HTC Vibe (Hanna, Ahmed, Nine, Prajapati, & Pantanowitz, 2018). Sirakaya and Kilic (2018) looked at high school vocational students and their use of AR software to train them in the building of motherboard assemblies. The researchers wanted to determine if there was an increase in achievement during the learning process when using AR technology. The comparison group used only the textbook to build the motherboards. It was found that there was a shortened build time involved for students that learned using the AR software over the students that used the book. Another study by da Silva, Klein, and Branãdo, (2017) used AR technology to help anatomy students model the human humerus bone. The technology allowed the students to use a real bone and enhance it with virtual overlays to make a more interactive version of the working of human bone. The students reported that the use of combining the virtual layers to the real human bone made it easier to understand the processes that occur in the model.

Another method to use educational technology used in the science classroom is related to citizen science. Citizen science engages individuals in a community to participate in scientific research through data collection and often online data analysis, such as, the University of Florida Lepidoptera study, or Maastricht University study of ancient microscopy. Students can use technology and their scientific knowledge on a variety of subjects to support scientific research. One example, Galaxy Zoo is one such site that asks citizens to look at pictures from the Hubble telescope and try to identify the types of galaxies found (Kruk et al., 2018). This is done with people from all over the world and no scientific training is needed. Data collection experience adds relevancy to the classroom and real time communication between the scientist and the classroom (Cox, Eun, & Simmons, 2015; Göbel, Cappadonna, Newman, Zhang, & Vohland, 2017). Students can participate in a range of data collection experiences from all over the world from a study on pollution effects on coral reefs to transcribing ancient papyrus texts (Dean, Church, Loder, Fielding, & Wilson, 2018; Williams et al., 2014). Ballard, Dixon, and Harris (2017) suggested that the actual use of scientific data collected at citizen science sites by students allows them to feel like true participants in the scientific process.

Another method of using educational technology is video making. The creation of videos can benefit teacher and student in the way they create and communicate their understanding of a concept (Kara & Bakirci, 2018). Video making can be used to help make science concepts simpler and more accessible. In one study middle school physical education students invited college students to share stories about their health on camera. The researchers found that the middle school students liked the realistic approach to learning about health when making the video. The students experienced real world problems dealing with classroom information as they interviewed and taped the various participants (Cox & Meaney, 2018). The videos were compiled into a mock television series to be shown school wide. Modeling safe and unsafe laboratory practices is another method of video making that helps students' model something they are learning in the science classroom (Kara & Bakirci, 2018). Christ, Arya, and Chiu (2014) used video making as a method of peer review and assessment in the science classroom by having students' video themselves taking part in various student designed science activities and reviewing the video with the creators of the assignment. Ibanez, Villaran, Di Serio, and Delgado (2016) had students create physics videos concerning topics they would normally have written a paper about. The students were more engaged and interested in the topic as they designed and created their videos to model and demonstrate the various science concepts. Hoban and Nielsen (2014) used a unique method of student designed slow motion video production to model the phases of the moon. The researchers allowed the students to design and film the moon phase model and found it to be a simple process to use in the classroom because of the wide availability of phones, tablets, or computers. The videos could be made on almost any device and researchers found the students were more engaged in the video making of the concept than just drawing it as they had in the past.

Further methods of using educational technology include game creation and digital storytelling. Liao et al. (2016) studied digital storytelling and game creation software as means to increasing girls' interest in STEM subjects. The students were asked to look at women in science and create stores that fictionalized the life of that person to create a more personalized story. The participants used Games 4 Girls, My

Avatar Games, and OpenSim for their digital creations. The use of storytelling, and movie making allowed the students to use creative thinking, and problem-solving skills to create something unique and personal (Liao et al., 2016). This use of educational technology encouraged artistic skills when working on assignment which the researchers found increased the student's engagement. It is this engagement that the researchers hoped would steer the participants toward more STEM-based learning in the future (Liao et al., 2016). Inchamnan (2016) used game play as a method to determine the creativity level involved in using educational technology such as game play and its effect on student interest in learning science. Fifteen high school students played one of four possible games; Portal 2, I-Fluid, Gunz 2: The second Duel, and Braid. These games allowed the students to participate in scientific observation, experiments, and validation activities as they played. The games were all open ended which allowed the students to choose various outcomes before reaching a final ending. The study used data from captured video to code verbalizations as students played and results from the 21-item Player Experience of Need Satisfaction survey that looked at 5 components in the lichert scale survey statements: in-game competence; in-game autonomy; in-game Presence; in-game intuitive control and in-game relatedness. The researcher noted an increase in motivation when game activities allowed for individual planning and strategies (Inchamnan, 2016). It was the open-ended challenges and opportunity to be creative in their decisions that the researcher found had more effect on the relatedness and motivation levels of the students. Although not artistic in nature the game play let the players make the choices much like artistic design. Jenson and Droumeva (2016) completed a case study concerning the process of game design and its effect on student motivation. Using student interviews, the researcher focused on identifying the 21st century skill levels of creativity, innovation, problem solving, collaboration, and digital media skills demonstrated during the game design experience. The analysis of the participant interviews shows that the first level students used a more concrete approach to game design. As the exposure to the open-ended style of game design increased at levels two and three the researcher found students demonstrated more creative thinking processes in their game creations and explanations of their designs. The students reported feeling that the ability to design their own game was more rewarding and challenging than the traditional method used in the technology classes (Jenson & Droumeva, 2016).

Another example of educational technology use in the classroom is science modeling software. The use of modeling to support science learning provides an effective tool for learners to understand new concepts. Research suggests that creation of hand drawn models increases a student's understanding of a science concept (Quillin & Thomas, 2015). Educational technology has allowed the original hand drawn models to improve into two dimensional (2D) virtual models which several studies found increase student understanding of concepts (Loertscher, 2014; Terrell & Listenberger, 2017). Terrell and Listenberger (2017) used classes of biochem I to determine if virtual software increased student understanding of molecular structure. The students used software such as BLAST, UCSF Chimera, AutoDock Vina, MarvinSketch to analyze and visualize protein structures. The researchers found a meaningful gain in student awareness after using the virtual modeling software (Terrell & Listenberger, 2017). The creation of 2D models on software has further evolved into virtual 3D modeling and printing which is a relatively new concept in the science classroom. Research has shown that traditional 3D physical models and drawings of science concepts help students gain understating of various ideas in science, so research today focuses on how 3D modeling and printing can do the same (Lin et al., 2017; Rossi, Benaglia, Brenna, Porta, & Orlandi, 2015). There is a focus today on research concerning the use of virtual 3D modeling to create 3D printed models and this type of modeling is a growing trend in STEM classrooms. It has been touted to be the technology of the future as mentioned by President Obama in his state of the union address in 2013, “3D printing is the wave of the future,” (Obama, 2013, p. 4). Some educators propose that it develops important transferable technology skills (Martin, Bowden, & Merrill, 2014; Trust & Malloy, 2017). A study by Bicer et al. (2017) found students perceived their work to be more creative when applying 3D modeling techniques to their models. The researchers found a meaningful increase in student perceptions about the need for creativity and problem-solving skills in STEM-related studies (Bicer et al., 2017). Another study performed by Trust and Malloy (2017) using teacher feedback looked at the teacher’s perception of the student design process when creating models with 3D printing. The researchers found a number of teachers felt that students that used 3D printing techniques for modeling developed increased creative thinking skills. A study by Lipson and Kurman (2013) suggested that the ability of 3D printing technology to permit students to visualize concepts virtually and then create a physical model increases the student’s ability to understand abstract concepts more clearly. Chien (2017) completed a study designed to determine the ability of 3D printing to increase student performance when creating carbon dioxide-based dragster cars in the classroom. The results showed a meaningful increase in performance ability of the cars when created suing 3D modeling and printing technology versus hand-built models.

Literature on educational technology in the science classroom ranges from movie making to virtual reality to teach science concepts. Data from study results in the last 5 years have led researchers to conclude that the use of educational technology can benefit students in a variety of positive ways. The gap that remains is how using technology to make digital artistic images might affect students' attitudes toward science. This gap is important because interest in science-related careers is waning and teachers with new and creative methods could help change that decline. While some studies explored the use of 3D printing (Trust & Malloy, 2017) and AR (Hanna et al., 2018) to engage students, this study explored creating digital artistic images that use scientific concepts. My study expanded on current research with the addition of digital artistic images being created and displayed in an art show. This can add understanding to the gap by demonstrating how digital art can increase student engagement. Creating digital images, like chemoscans, in the science classroom can help students learn the use of photography, image processing software and 3D modelling software which can be transferred into the use of 3D printing (Hess, Garside, Nelson, Robson, & Weyrich, 2017).

Visualization in the Science Classroom

For science teachers the use of visualizations has always been a way to help a student understand a new concept. When the term *visualization* is used in science it means realistic graphic rendition of the concept (Wainer & Friendly, 2018). Science has relied on visualization to help regulate the observable world and maintain views of various phenomenon for worldwide consumption. Scientific visualization also serves to preserve information for future generations and can serve as means of communication for people that have never viewed something or to want to understand more about a subject. Sometimes visualizations are abstract and only hint at their derivation which can cause the viewer to ask questions about the image. These questions can lead the viewer to a more profound understanding of a concept as they try to answer those questions (Wainer & Friendly, 2018).

With the creation of the NGSS the use of scientific visualizations will become even more prevalent. The NGSS (2019) standards have been adopted in some form by all 50 states in the United States and have incorporated new ideas called cross cutting concepts. These cross cutting concepts endeavor to link sciences together through the use of models, systems, design, and function which all require visualization skills to accomplish. The world is complex and offering students methods to construct imagery of what they learn is an important step towards understanding (NGSS, 2019). Studies have shown the numerous pictures, graphs and charts found on standardized tests from the New York Regents test underscores the importance of visualizations in science and requires the need for student engagement with visualization in the science classroom (LaDue, Libarkin, & Thomas, 2015; New York Department of Education, 2010). In order to understand the role of visual arts in the teaching and learning of science, researchers looked at the use of visual arts in the science classroom. Thirty one third grade students were asked to draw specific science concepts such as the insects life cycle and then present their drawings as they explained the concept. The teachers in the study reported positive changes in students attitudes toward learning science when using drawing and presentation of the concept being taught (Dhanapal, Kanapathy, & Mastan, 2014).

Visualization can be a potent force for learning and developing critical thinking skills. Katsioloudis, Dickerson, Jovanovic, and Jones (2016) used a comparative study to determine the spatial ability of 74 science education students in an engineering course. The students were placed into three groups and asked to create sectional view drawings. The researchers concluded that there was a correlation between the development of spatial skills and the use of hand drawn sketches in the learning process. The researchers felt the results could help educators find new methods to increase the retention rate of engineering students if their spatial skills improved using visualizations. The use of 2D and 3D visualizations in science has been well documented through all sciences from chemistry to anatomy (LaDue et al., 2015). It is the artistic interpretation of scientific models that has not been widely accepted. The concept of using art in science is often seen as a new way to do the same sort of 2D and 3D models that show a realistic visualization of a science concept.

Hegedus et al. (2016) created a cross curriculum team of a high school biology teacher and her students with a local university biology class. The students were tasked, in a half day symposium, to work together to create arts integrated visualizations that demonstrated science concepts. The students were able to communicate their ideas with creative methods. The students worked in a collaborative manner to model concepts realistically but with an artistic flare. For instance, students created embroidered models of the cell, leaf imprints, songs, or sculptures; but visualizations created in the study did not allow for abstract models that could be interpreted in various ways (Hegedus et al., 2016). However, students had varying views of the experience. The majority reported that creating artistic models made the learning more interesting, but other students reported that creating artistic models was time consuming and was not a good use of their time. The students who enjoyed creating the art in science class may realize that science can be seen as more than just memorization activities. What is not understood is whether the creation of abtract artistic visualizations of science concepts promote a more positive attitude toward science learning. The idea of combining nonrelated curriculum with the use of visualization techniques to help the learning process is not new. Research conducted in at a small public college in the southeastern United States, used 20 students enrolled in an Introduction to Interdisciplinary Studies course felt after participating in activities that combine unrelated curriculum. The researcher found that when students understand use of integrated curriculum they were more likely to continue interest in participating in interdisciplinary studies. The researcher reported that participants attitude toward learning became more positive as they participated in the activities that combined subjects like art and science (Everett, 2016).

Using visualizations in various forms in different disciplines seems to promote critical thinking skills. Smith, Qayyum, and Hard (2017) conducted a case study of five college volunteers who used software visualization technology to improve student search abilities in a university library. The researchers found that 4 out 5 students demonstrated increased engagement in the search process when using the visualization software and increased student engagement in the search tasks. In addition to college students, another study looked at 50 sixth grade public school children in Istanbul. The students were asked to create a visual when solving fraction problems. The researchers reported that the students that could not visualize fraction problems were less successful in finding the correct answer. The conclusion being that teaching fractions with visual models can create a more relevant experience for the learner to support their reasoning skills. By the same token, visualizations help students with not only with difficult math concepts but also with other content areas. Herga et al. (2014) demonstrated that having students create different visualizations in a chemistry classroom increased their interest and helped them understand complicated chemical concepts. The use of visualization techniques in the learning process promotes understanding in a wide range of skills and subjects.

The literature on the use of visualizations in science ranges from watching Power Point images on a screen to creating needlework models of cells. Data from various studies over the last 10 years have led researchers to conclude that the use of visualizations in the classroom increases student interest and ability to learn. The gap that remains is how interpretive artistic digital creations can lead to a more positive attitude about science or affect learning at all. This gap is important because increasing interest in learning science can lead more students toward STEM-based careers in the future. Although some studies explored how girls were more interested in learning when using visualizations and other research determined that spatial skills increased when drawing visuals as they learned, this study explored how creating interpretive digital art can increase student interest in learning science (Bilbokaitċ, 2010; Katsioloudis et al., 2016). Although realistic visualizations and students' designs have been found to help students think critically (Everett, 2016) and comprehend science (Dhanapal et al., 2014), the effect of creating interpretive artistic digital images has not been well studied.

Science Teaching Methods and Art

Lack of student interest in science has been identified as a major reason behind students' not following STEM careers (Conley et al., 2013). Uitto (2014) found students who were interested in biology followed a career in a biology related field which supports the idea that if a student has a postitive feeling about a subject they are more likely to look toward a career in that field. Many times, students, especially women, felt pushed away by the austere nature of STEM classes and they sought experiences that would lead them to greater social interaction (Thoman, Arizaga, Smith, Story, & Soncuya, 2014). Further investigations from (McEwen, 2007; Wolter, Lundeberg, & Bergland, 2013) found student motivation was affected by the way that science was being taught. One conclusion of these studies was that students were often not engaged by the strict method that was used to teach science in many classrooms. They reported feeling disconnected from the material they were learning. These feelings often resulted in students deciding not to continue their enrollment in science classes.

Another factor that is important to consider when looking into research concerning student interest in science is why certain students follow STEM-based careers. White (2013) found that early interest in math and science can have an influence on career development and persistence in following STEM careers. The more quality math and science classes students acquire during their education leads to greater success in STEM-based careers and a higher likelihood to follow a STEM-based career (Swift & Watkins, 2004; Wai, Lubinski, Benbow, & Steiger, 2010).

When considering the need for students to become interested in STEM subjects, one step would be to use diverse disciplines like art and science. The purpose would be to transform a student's attitude concerning the subject from boredom or fear to pride and accomplishment (Marshall, 2014). The integration of art and science into STEM subjects has the potential to transform students' learning and their understanding of the science discipline. Along those same lines, integrating science and art allows educators to imagine how this partnership of science and art can lead to new models of pedagogy in an education system that is desperately trying to find ways to engage students in learning (McLaughlin, 2010).

The need for engaging students in the science classroom was supported by research from the Business Higher Education Forum (2014) which recommended that the United States should try to engage non-STEM students into STEM activities. The hope is that developing more opportunities for non-STEM majors to explore STEM-related fields could lead them toward a career interest in STEM. Their findings from 2013 discovered that about 41% of ACT-tested high school graduates reached math readiness and 37% reached readiness for science. The problem was that a large portion of the students that achieved readiness were not interested in STEM careers. It has been suggested that introducing students to STEM related activities earlier in their education and redesign beginning courses that move away from the standard lecture method and incorporate more hands-on STEM based activities (Kearney & Harris, 2013).

A plethora of research supports the notion that the inclusion of art in an interdisciplinary curriculum increases higher level thinking skills (Katanski, 2013). Integrating the arts into content areas can give students the opportunity to engage in new and varied approaches while gaining positive emotional responses to learning, understanding others, and communicating their own ideas (New York State Education Department, 2010). The use of art encourages critical thinking skills and imagination (Petto & Petto, 2009). Studies have suggested that the use of art affects student motivation because the creation of art involves them personally and supports divergent thinking (Hardiman, Magsemen, McKhann, & Eilber, 2009). Hardiman et al. (2009) and Gebbels, Evans, and Murphy (2010) found that students experienced a sense pride from knowing that the products they created in various student-centered activities had value other than as just another assessment that would be graded. Creating artistic images and displaying those images could help students feel pride in their work which in turn could cause a more positive attitude toward science (Katz-Buonincontro, 2011).

The chemoscan activity allows students to create a meaningful art project in which the participants can express themselves while learning new science concepts. Gillespie (2014) supported the need to begin the use of more artistic digital creations in the regular classroom. Combining art and science could enhance students' learning as they develop critical thinking skills. This type of learning is an inherent part of the new STEAM curriculum, which attempts to bring a more balanced approach to the learning by including STEM curriculum integration with art (Connor et al., 2015). The STEAM curriculum often involves project-based learning with attention to technology and interdisciplinary teaching, which is a method where a problem is proposed and all curriculum is used to solve it (Annetta et al., 2014). Students working in STEAM units not only strengthen their learning within the disciplines, but between disciplines, through opportunities to explore and to make connections between art, music, mathematics, science (Sousa & Pilecki, 2013). Recent studies found that STEAM-based curricula produced a higher percentage of students interested in pursuing math and science careers because they were drawn to the disciplines through the transdisciplinary approach encouraging the integration of various modes of inquiry (e.g. creative process, technological problem solving) (Annetta et al., 2014; Herro & Quigley, 2016).

The New Media Consortium Horizon Report (Johnson et al., 2016) described STEAM as a rising trend in K-12 education and detailed a few examples of schools around the United States focusing on STEAM education. Yet, little research exists defining what STEAM teaching practices are or explaining how teachers enact those practices in their classrooms (Kim & Park, 2012; Yakman, 2008). The incorporation of art into the science or general classroom supports interdisciplinary work, which has been shown to engage the student more in the learning process (Todd & O'Brien, 2016). Studies have shown that interdisciplinary collaboration increases understanding of subject matter when students from one discipline are partnered with a different discipline. An example of STEAM work is a science class and a history class working on a project which teaches ecosystems using famous historic sites (Basow, Ingalls, & Sethi, 2009; Everett, 2016).

Summary and Conclusions

Literature on educational uses of technology to create art in the science classroom ranges from visualization techniques to 3D printing. Data from study results in the last 5 years have led many researchers to conclude that using technology in the science classroom will help students develop 21st century learning skills. Literature concerning the need to increase student interest in science ranges from research that has expressed concerns about the possibility that the United States would become only a consumer of new technology and not a developer (Pew Research Center, 2014) to studies that have found that increasing interest in science using art could increase science attitude and creativity (Helding, 2011; K., Kim, 2011; McLellan & Nicholl, 2013; Ness, 2015). What has yet to be explored is how digital artistic designs used in the science classroom might increase creativity and critical thinking skills.

Literature on initiatives to increase students' interest in science range from the use of art to increase cognitive abilities (Sousa & Pilecki, 2013) to supporting creative ability in the classroom. Research has found that artistic endeavors using technology such as Sketch 2.0 in an engineering design-based activity helped students solve problems by allowing them to make decisions about their own learning increasing their positive attitude about learning (Jeon & Lee, 2014). Research in this field also suggests that the perception of science being difficult has led to students' negative attitude toward science and that reintroducing self-directed projects like digital artistic activities into the learning process could bring about positive change toward learning (Patall et al., 2018). Quinn and Lyons (2011) found that many students believe that learning science will be hard even before they start which leads to a negative attitude toward the subject. While there is literature exploring various ways to increase creativity by using art in science classrooms, none specifically address 2-D digital art as a way to potentially improve attitude toward science.

The literature concerning educational technology use in science courses, ranges from the use of AR technology such as Google Glass or Microsoft Hololens to digital media techniques (Hanna et al., 2018; Hantono et al., 2016). The use of citizen science is increasing rapidly, and this technology lets students become a part of a large pool of people collecting data for real researchers (Kruk et al., 2018). Educators are looking for new ways to present science information to students and these recent technological advances allow them to experiment with science teaching methods that have never existed before (Hess et al., 2017). The use of innovative technology such as 3D printing, virtual-reality, and digital art technology such as chemoscans is still young, and research is just beginning on these new methods for teaching science which will help inform the lack of understanding of the influence of technology use in science teaching.

The literature on visualization in the science classroom ranges from the use of 2D and 3D visualizations in science to unique integrated visualizations to demonstrate science concepts (Hegedus et al., 2016; LaDue et al., 2015). Educational technology has allowed the original hand drawn models to improve into 2D virtual models which several studies found increase student understanding of concepts (Loertscher, 2014; Terrell &

Listenberger, 2017). The use of modeling to understand science concepts has kept pace with the innovations in the industry as more researchers find that typical 3D models from the past may be replaced with 3D printing models as studies find connection between 3D modeling and printing and to increase understanding of science concepts. While there is research related to visualization and modeling in science classes, simpler digital artistic teaching strategies have not been examined for their effectiveness with high school students; particularly in connection with how these might influence students' attitudes toward science.

Literature concerning science teaching methods and art encompasses research from Gillespie (2014) finding that using art in the regular classroom can enhance students' learning to the use of the STEAM curriculum to increase student science attitude (Connor et al., 2015). Researchers have found that some students find science classes to be rigid in the nature of the teaching and when teachers used activities that provided greater social interaction students enjoyed learning more about science (Thoman et al., 2014). Other studies, including McEwen (2007) and Wolter et al. (2013) showed that students feel more of connected with learning when using activites that supported social interaction and artisitic creatvity, but no research has been conducted lately on the influence of specific art interventions with science students

The gap in knowledge concerns the lack of research that has been done to show how the intersection of technology and the creation of artistic digital images impacts high school students' attitudes toward learning science. A similar gap in the research exists concerning art and educational technology in the science classroom specifically related to research that examines the relationship between digital art technology to create artistic designs and the improvement of student's attitudes toward science. This gap is important because it at may help teachers find new and improved methods for teaching while helping students like it at the same time. While technology use in science classrooms has been studied in various ways such as 3D printing technology (Chien, 2017) and digital storytelling (Liao et al., 2016), the use of digital art and science has yet to be examined. This study expanded on current research by adding more understanding related to student science attitude from the aspect of making artistic digital images. Findings from this study may add understanding to the gap by adding another facet to existing research concerning students' interest in science and the digital artistic connection.

Chapter 3 includes a through description of the research design. The chapter begins with the research questions which drive the study. Next, the research design describes how the study approached the investigation. This setting and sample section outline the approach of, the research setting, the population to be used and methods of data collection and analysis used. The instrument section describes and justifies the instrument used in the study while the preparation of data section describes the methods used to prepare the data for analysis. The data analysis section provides an in-depth interpretation, analysis, and synthesis of the results/findings. The limitations and delimitations of chapter three identifies potential weaknesses of the study and the scope of the study. Chapter 3 ends with a look at researcher ethics and the ethical considerations pertaining to participants.

Chapter 3: Research Method

Introduction

In this naturalistic, quasi-experimental quantitative study, I examined if the high school student creation of artistic digital chemoscans influences their attitudes toward science as seen in the seven subscales of the TOSRA. The research problem under study was that many high school students do not have a positive attitude toward learning science.

In this chapter, I present an overview of the research design and its relationship to the research questions in this study. Explanations of the methodology and instrumentation are provided along with the procedures for recruitment and participation in the study. The role of the researcher is also clarified with specific information concerning preparation of the data that were collected. I discuss the data analysis strategies as well as the limitations and delimitations that could have affected the analysis. The chapter also includes information concerning the ethical procedures and responsibilities of the researcher.

Research Design and Rationale

In this study, I related the making of chemoscans (i.e., the independent variable) to changes in a pre- and posttest of the TOSRA (i.e., the dependent variable), given to all ninth grade students in the participating school. Archival TOSRA pre- and posttest data were provided by the cooporating school district after the implement of chemoscan PD and implementation. The treatment group experienced the chemoscan lessons, while the comparison group did not experience chemoscan lessons but were otherwise similar in student profile and physical science class. The covariate of teacher effect was analyzed.

Research Questions and Hypotheses

RQ1: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the social implications of science.

RQ 2: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the normality of scientists.

RQ3: The creation of chemoscans in the physical science classroom will improve students' attitudes toward a career interest in science.

RQ 4: The creation of chemoscans in the physical science classroom will improve students' attitudes toward scientific inquiry.

RQ 5: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the adoption of scientific attitudes.

RQ 6: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the enjoyment of science lessons.

RQ 7: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the leisure interest in science.

Null Hypothesis ($H_{0}1_{0}$): Students' attitudes toward science are not affected by the creation of chemoscans.

Alternative Hypothesis 1 ($H_{1}1_{1}$): Students' attitudes toward science will be affected by the creation of chemoscans.

Alternative Hypothesis 2 (H_01_2): Students' attitudes toward science are affected by the creation of chemoscans when considering teacher effect.

In this study, I employed a naturalistic, quasi-experimental design that addressed the constructs of the TOSRA instrument. This activity had a time constraint of 9 weeks between the pre- and posttest. The benefit of the quasi-experimental design is the inclusion of a pretest to determine baseline scores, allowing for compensation for nonequivalent groups (Cook & Campbell, 1979). The design choice is consistent with research designs needed to advance knowledge in the discipline because it allows for the comparison of the effects of making chemoscans to effects of not making chemoscans under similar conditions. The intervention choice was suitable for this study because it was specifically designed to test high school students' science attitudes.

In this study, I also utilized a postpositivist approach within the quantitative approach. I cannot be sure about the conclusion reached when studying the behavior and actions of humans, but I can argue that the research was conducted using careful observation and a valid measuring instrument. The TOSRA is a nationally accepted instrument designed for measuring students' attitudes toward science (Fraser, 1981). Historically, research concerning attitudes toward science have been qualitative, and at the time of this study, no research had been done concerning the use of chemoscans in the classroom because the chemoscan process was newly developed.

An advantage of the quasi-experimental design is that it allows the researcher time to complete the work in a school setting and bypass the logistical design problem of the inability to use a participant pool that models a true representation of the U.S.

education system as a whole (Creswell, 2014). Another benefit is in using quantifiable data, which has a different set of possible misinterpretations than a qualitative study. At the end of the research period, I made the results available to stakeholders and community in the form of a short report distributed to all stakeholders and community members at the chemoscan art show after the study had ended.

Instrumentation and Research Design

In this study, I used a published instrument called the TOSRA developed by Fraser (1981). This instrument was particularly appropriate because it was specifically designed to measure students' attitudes toward science in high school (Fraser, 1981). Fraser provided me with permission to use and modify the TOSRA (see Appendix B). The 30-minute survey consisted of 70 Likert-type items with survey responses of strongly agree, agree, undecided, disagree, and strongly disagree. The strongly agree response was given a numerical value of 5, with a decrease in value assigned for each category so that strongly disagree was given a numerical value of 1.

The TOSRA uses seven identified attitudes that students manifest but do not always realize in relation to their feelings about scientists and science (Fraser, 1981). There are seven subscales for each of the attitudes encompassed in the TOSRA: Science Effects on Society, Normality of Scientists, Scientific Inquiry, Willingness to Revise Opinion Based on Scientific Evidence, General Feelings About Science (Like or Not Like), Career Interest, and Science is Fun. At the time of this study, there was no research available concerning the creation of chemoscans and the effect their creation may have on the affective learning outcomes of the TOSRA.

In the experimental group, the chemoscan experience served as the independent variable and was seen as the chemical reaction the students' implemented and scanned. The dependent variable was the gain or loss in attitudes toward science, measured by pre- and posttest scores on the TOSRA. At the beginning of a 9-week grading period, four classes of ninth grade physical science students took part in the study for a total of about 230 students. Experimental group teachers were trained in the chemoscan process to ensure fidelity of the process. The teachers and students were provided with complete instructions concerning chemoscan creation. The teacher demonstrated the process before students began their own creations. I did not interact with the students.

The students had 90-minute-long classes, so the testing took place during their regular classroom period in the designated school testing area. The participants came to class as they normally would and took the test as they would on any normal standardized test school day. The test was adminitered by the school district test administrator following school district test procedures. The participants left the classroom the same way they did on any school day at the sound of the bell that ends the class period. At the end of the 9 weeks, they took the test again using the same procedure. The test was given electronically over a 45-minute time period.

The actual chemoscan lesson (see Appendix A) occurred six times for each student during the 9-week grading period. The students created chemoscans when introduced to chemical reactions, chemical bonding, and acids and bases in class after the lessons were presented. The actual digital image was modified into the students' art work in an online, digital-editing platform after scanning the chemical reaction. The completed chemoscans were displayed in a school and community art show after the study had ended. The students took the pretest at the beginning of the 9-week grading period and took the posttest at the end of the period.

In a study of similar design, Welch (2010) used the TOSRA to examine st udents' attitudes toward science after participating in the FIRST robotics competition. The treatment period was a 6-week robot build period working 3 days a week for 1 hour, the students participated in a robotics competition. The researcher concluded that the results from the TOSRA demonstrated a more positive attitude toward science after the 6-week period buulding period and competition.

I chose a 9-week grading period as the lesson period because the chemoscans would be able to be created six times during that space of time. Those students who did not agree to participate in the study took an ACT practice test that is a normal part of their curriculum instead. From the six chemoscans the students created; they chose what they considered to be their best work for the community art show.

I looked at the relationship between two variables in this study: chemoscans and an increased positive attitude toward science. The relationship between two variables may be one of association or one of causation (Creswell, 2014). The relationship being tested was the possible association between the creation of chemoscans and changing students' attitudes toward science.

Methodology

In this methodology section, I state the research questions and discuss population, sampling procedures, procedures for recruitment, participation, and data collection. I also address instrumentation and discuss operationalization of constructs. I end the section with a description of the data analysis plan.

Population, Setting, and Sampling Procedures

The target population was ninth grade students participating in physical science classes in one rural high school. Six physical science classes were used, which were taught by four different teachers. The typical class size was 25 to 30, which gave a possible participant pool of 150. The calculated sample size was 116, so this reached the minimum sample size necessary when excluding those students who did not participate and other attrition. The limitations in acquiring a nonrandom sample of students necessitated the use of the quasi-experimental method in this study. The participant pool was considered a convenience sample because they were from only one school in a rural school district.

Convenience sampling is a nonprobability sampling method that uses a population that is convenient to the researcher (Creswell, 2014). The participants in this study were chosen based on convenience, which can lend itself to bias error (see Creswell, 2014). Another limiting factor concerns the covariance of teaching style of the different teachers. It is possible that teaching style had an effect on students' attitudes and acted as a covariate. There were four teachers involved in the research project. Two teachers' classes were the control groups and did not experience the chemoscan lessons, while two other teachers' classes did experience chemoscan lessons. To check for teacher as the moderator, I used a dummy code to determine which teacher was teaching each class.

The school district administered the TOSRA for its own purposes and has allowed me access to the archival data for this study. The TOSRA was given to all treatment and control classes in the pre- and posttest format. The school district oversaw all population samples and was responsible for how the participant sample was drawn. The participants were not required to take the TOSRA, and the choice was determined on the student level and all parental consent forms, collected by the school, at the beginning of the school year, which are stored in a safe, secure location provided by the district. For purposes of the research, the participants were defined as any ninth grader taking physical science classes in the test school. Students with Individualized Education Plan or 504 plans did not participate in the activity. These students worked with their special needs teacher on their Individualized Education Plan goals as mandated by district policy.

I analyzed teacher effect by dummy coding which teacher the TOSRA test came from as the data were inputted. For instance, teachers were arbitrarily assigned a nominal variable: T1 through T6. For each class, a value of 1 was given to the specific teacher who taught that particular class, and a value of 0 to the other teachers as the data set was created. Repeating this procedure for each teacher allowed checking for teacher effect as a moderator using multiple regression calculation. Multiple regression is an extension of a simple linear regression (Creswell, 2014). This was used to predict the value of a variable based on the value of two other variables.

A power analysis, using G power (Faul, Erdfelder, Lang, & Buchner, 2007), determined the sample size of 116 with a predicted power of .75 and a predicted effect size of .3. When considering the analysis of research data, it was important to look at the power and effect size to calculate the sample size needed for the study. Effect size was used to determine the effectiveness of the lesson and was a measure of the difference between the study groups. Cohen (1988) provided ranges to help understand effect sizes which puts the effect size of .3 in the moderate range. The calculated sample size of 116 left enough attrition room for participants that are absent, have consent issues, or decide not to participate.

Smith (2006) used the TOSRA to research the effectiveness of an integrated high school science curriculum on student science attitude. Tenth grade students in Missouri were given the pre- and posttest TOSRA after participating in either a normal biology or integrated biology class. The calculated effect size (partial ETA squared = .047 or 4.7%) of this study equated to a small to moderate effect size similar to the predicted effect size of .3 (Cohen, 1988).

Procedures for Collection of Archival Data

Survey data for this study were provided by the school district which gave the TOSRA to ninth graders. Parental permission was given and maintained by the participating school district. The school district procedures for collecting student data for this study included ninth grade students in physical science classes at the high school in the district. The school district kept parental permission forms on file.

The school district administered the TOSRA pre- and posttest in the physical science classrooms electronically on designated test days for the pretest and posttest during the 9-week study period. All testing procedures were administered by a district certified test administrator. No names were used to identify subjects, but random index numbers were used to separate pretest and posttest data. No student interviews were conducted to determine if the chemoscan process affected student interest in science.

The necessary permission forms for data access were given to students and parents at the beginning of the school year. The permission forms are maintained by the school district in each student's permanent record. The permission forms are discarded when the students graduate from high school. The procedure for gaining access to the data set for analysis takes place after the posttest was given. The district allowed me access to the data after the study was finished. I acquired the archival TOSRA data directly from the school district. The data were maintained by the school district until after a student has graduated.

Instrumentation and Operationalization of Constructs

Fraser (1981) determined the TOSRA reliability coefficient from Cronbach Alpha for the seven subscales to help determine validity of the instrument (Table 1). The Cronbach alpha test as used to estimate the ability of TOSRA statement to measure specific attitudes when used over time (Fraser, 1981). Cronbach's alpha values from Year 7 ranged from 0.66 to 0.93 and 0.64 to 0.92 in Year 8. Year 9 had a range of 0.69 to 0.88 and Year 10 has a range of 0.67 to 0.93. Table 2 shows the values separately for each level of Cronbach's alpha coefficient for each TOSRA scale. Frasier (1981) suggested that the scores demonstrate validity and reliability.

Table 2

Cronbach's alpha values for TOSRA scale year 7 to 10

Scale	Cronbach's alpha values			
	Year 7	Year 8	Year 9	Year 10
Social Implications of Science	0.81	0.82	0.75	0.82
Normality of Scientists	0.72	0.70	0.72	0.78
Attitude to Scientific Inquiry	0 .81	0.82	0.81	0.86
Adoption of Scientific Attitudes	0.66	0.64	0.69	0.67
Enjoyment of Science Lessons	0.93	0.92	0.87	0.93
Leisure Interest in Science	0.88	0.85	0.87	0.89
Career Interest in Science	0.90	0.88	0.88	0.93

Note. Reprinted from *TOSRA: Test of science-related attitudes handbook* (1981) by B.J. Fraser. (1981), Hawthorn, Victoria: Australian Council for Educational Research. Reprinted with permission of B.J.Fraser.

The TOSRA has been used many times since its creation as an instrument to measure students attitudes and perception of science. The TOSRA was used by Rana (2002) to determine the science attitudes of students in Pakistan, which had a reliability coefficient of 0.9104. Fraser and Fisher (1981) again used the TOSRA on 116 eighth and ninth grade students while conducting research on anxiety and science-related attitudes. In study on gender differences in attitude toward science, Smist, Archambault, and Owen (1997) administered the TOSRA to 572 high school students. Wood (1998) used the TOSRA to determine if there was an effect on students attitudes toward science when using specific educational software. The study found no siginificant difference in students attitudes when using the educational software.

The TOSRA was later modified by Quek, Wong, and Fraser (2001) into the Questionnaire on Chemistry-Related Attitudes. This modified version of TOSRA was used to examine students attitude toward chemistry specifically. It was given to 1,592 chemistry students. Smist (1996) used the TOSRA and conducted a research study with 411 secondary students concerning their attitudes toward science and how self-efficacy is related to science attitude. The researchers found it to be a valid and reliable measure of the science attitude constructs because it has been widely used, and designed specifically for high school students.

The TOSRA was also used in 2002 to measure secondary student science attitude in Pakistan and was translated into Urdu (Rana, 2002), and administered it to 2,144 students in the Punjab province in Pakistan. All of the seven scales of TOSRA were used in this study. The reliability coefficient for TOSRA in this study was 0.9104.

In 2003, Lott used the TOSRA to determine whether students' science attitudes and their interactions with their teachers were related. The study found that there was a positive influence on student science attitude when the students had positive interpersonal associations with their teacher. The TOSRA was also administered by Adolphe (2002) for the measurement of attitudes among junior secondary science students in Australia and Indonesia. A similar research study, translated into Spanish, was used to determine science attitudes of 223 fourth and sixth grade students (Adamski, Peiro, & Fraser, 2005). Research conducted by Wolf and Fraser (2008) tested 1,434 students using the TOSRA to determine students' science attitude. Eccles (2007) measured middle school student science interest in Florida. Fraser, Aldridge, and Adolphe (2010) used the TOSRA in a recent study to determine science attitude using 1,161 students from Australia and Indonesia. Welch (2010) studied 80 students involved in a robotics competition and used the TOSRA to determine if their participation increased students interest in science.

In my study the dependent variable was the change in subscale scores on the TOSRA. The TOSRA is a 45-minute survey that consists of 70 statements to discover students' attitudes toward science. The survey responses were strongly agree, agree, undecided, disagree, and strongly disagree. Sample TOSRA statements include: Money spent on science is well worth spending; Scientists usually like to go to their laboratories when they have a day off; I would prefer to find out why something happens by doing an experiment than by being told. The sub scale scores were calculated by adding the point value for each subscale answer.

Preparation of the Data

In order to assess the reliability of the TOSRA, Cronbach's alpha test was used on archival data collected from the school district. The term reliability refers to the ability of a test to consistently measure the concept being tested. In this study, the alpha test was used to determine how well the TOSRA measures students attitudes toward science.

As in all research, there is always a possibility of data values that were considered outliers. An outlier in a data set is one that seems to have a value that is abnormally different from the other values in a data set. What was considered abnormal was based on all values from the collected data. Statistical outliers can often cause a problem for data integrity. Outliers can distort the estimate of central tendency (Strutz, 2010). The methods for handling outliers begin by being sure that the outlier was not caused by incorrectly entered or measured data. If it is obvious that the outlier was caused by error, then it was dropped. If the outlier did not affect the end result but changes assumptions, then it was dropped with a footnote describing the reasons. If the outlier affects both results and assumptions, then it was not dropped but was run both with and without to make a note of the difference. If the outlier demonstrated extreme changes then it was dropped and not mentioned.

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Data profiling methods were used to analyze the data to ensure that coding errors do not exist. This process included making sure that all entries were complete and when errors were found examining the cause of the error and using the information to be sure the same sort of error was not made again. The process required consistent and reliable data entry methods that do not overload the researcher causing more errors. The TOSRA was given to students electronically and the data were sent directly to the test administrator in spreadsheet format to help prevent data entry errors. Standardizing the data entry process were important in reducing data entry errors. The subscale titles were entered using the words which best represent the subscale.

Data Analysis Plan

The descriptive analytics of the IBM SPSS software used in this study included frequency, which is the count of the number of times a particular value in the data set appears. Values were expressed as percentages and mean, median, and mode calculated along with maximum and minimum values of reported data. It was necessary to look at the differences and relationships between data sets.

Missing data are seen very often in educational research. There are many reasons for missing data, such as participants who do not take both the pre- and posttest, or do not finish taking the test. For example, in this study there is a calculated sample size of 116 with a power of .75, but missing data could reduce the effective sample size and change the power. The method for handling missing data for this study was Listwise Deletion, which discards any data with missing values (Cheema, 2014). In a school setting, there were situations that kept students from completing the tests as needed. For instance, students who took the pretest but were absent for the posttest, the missing data were not included in the final analysis.

Parametric tests were used to test all assumptions for validity by looking at interval data, independent scores with no covariates, normality, and homogeneity of variance. The research questions were tested separately and cumulatively. One of the issues that had to be dealt with in this study was covariates that may affect the resultant data. The fact that the participants whad different teachers during the study could affect the outcome. The data in this study was analyzed with the multiple regression method which allowed for the analysis of the corovette covariate of teacher effect. The multiple regression test lets the researcher try to determine what is the best predictor of the outcome of an experiment. The degree that two or more covariates are related to the dependent variable is denoted with the correlation coefficient *r*. An *r* value range from -1 to +1. If the *r* value is close to 0 then there is no relationship between the values being studied.

The data collected from the TOSRA were ordinal. There are seven categories on the TOSRA with 10 questions each for a total of 70 statements. Each statement was coded individually using the number 1 through 5 to determine its level. The statistical software SPSS has a variable view where the data will be defined by numbers 1-5. The number 1 equals strongly agree, 2 equals agree, 3 equals not sure, 4 equals disagree, 5 equals strongly disagree. The data view let me identify each of the 70 statements with identifiers like science careers, or scientists are weird. The variable names were categorized as comparison and treatment groups. Teacher code was added to look at teacher effect as a nominal independent moderator variable to the multiple regression analysis. This allowed me to use the analysis to determine what percent of any variance was due to teacher effect. Each subscale of the TOSRA was run independently as the dependent variable.

Multiple regression analysis was used to test if other variables have had an effect on the outcome such as teacher effect. The multiple regression test allowed for handling the violation of assumptions that may occur due to lack of randomization. Along with the multiple regression to determine the strength of the relationship between variables. In this study, the tested variables are the making of chemoscan students and non chemoscan comparison groups, with the added covariate of teacher effect and non comparable groups if necessary.

A test of the hypothesis determined there was no difference between pre- and post test data, since the significance test failed. There was no difference between pre- and post test data, since the significance test failed. There was no real effect size as significance no significance was found. This test was used determine an observed significance level (Greenland et al., 2016). This is known as the *p* value and is normally used to determine if the null hypothesis has statistical significance. The conclusion of the research was not based on the *p* value. If the *p* is significant, then it is necessary to look at effect size (% variance accounted for) of the treatment and teacher codes. This measure looked at how the change in group pre- and posttest data were actually related to the independent variable by determining how well the treatment worked.

Threats to Validity

The results of the research were affected by human interaction and as such care was taken to minimize threats to internal validity. The participants had contact with each other during the school day. The comparison group did not make chemoscans during the activity period. They were able to make chemoscans after the posttest had been given. The fact that the participant pool came from the same school where I work was a possible threat to internal validity. To minimize this threat I was not involved in any classroom instruction or TOSRA data collection.

External and Internal Validity

The participants in this study were not randomly assigned to their physical science classes because they are put into the classes as needed by the school district. This might have reduced the effect of the experimental procedure and may have lead to internal validity problems. This situation is usually associated with the quasi-experimental design so posttest differences between groups could be attributed to differences between nonrandomized groups and not the intervention (Dimitrov & Rumrill, 2003). This problem was also addressed with a multiple regression analysis of the data which allowed the comparison of the dependent variable to the dummy coded covariate and the independent variable.

Inconsistent implementation of the chemoscan process by the classroom teacher is a limitation that was addressed through proper training. All teachers involved with the research participants were trained in the chemoscan process to ensure fidelity of the chemoscan lesson implementation, during the teacher workdays available before the start of the 9-week grading period. The training lasted about 1 hour. The teachers and students were provided with complete instructions concerning chemoscan creation. The teacher demonstrated the process before students began their own digital creations. If for some reason a teacher was unable to understand the process or did not want to participate there were substitute teachers available. I was not in the classroom during the creation of chemoscans, so it was up to the classroom teacher to be sure and follow the procedures as trained.

Another threat to internal validity was interaction by the participants during the school day. To minimize this threat participants did not have access or see any of the chemoscans produced by others until the community art show which occurred after the post test. The participants had contact with each other during the school day. The use of a comparison helps to mitigate internal validity issues because the comparison between the control and the treatment group.

Selection procedures can also pose a threat to internal validity. This study used a convenience sample which made it difficult to prove that the relationship between independent variable and dependent variable. This internal threat was reduced by using all ninth-grade students in physical science not just chosen classes. This same issue with the convenience samples can cause a threat to external validity because it is more difficult to generalize the data. The use of all ninth grade physical science classes also reduced that threat because all groups are equivalent at the beginning of the study.

The study was completed in a rural high school a context which may not provide generalizable results to students in suburban and urban populations. The participants in this study were about 80% White, and not representative of a more ethnically diverse population. Participants were limited to ninth grade students; therefore, results may be limited in their applicability to students in other grades.

This analysis did incorporate measures of other factors such as gender and socio-economic status. In fact, the influences of students' and parents' educational backgrounds were excluded, although many educators believe that these factors may interact in affecting students' learning outcomes (Marksteiner & Kruger, 2016). The sample size is another limiting factor, a larger sample size would provide data that could be more readily generalized.

Skorupski and Carvajal (as cited in Freedman, 2010) described threats to internal validity as:

> Increasing reliability without increasing (or at least maintaining) validity is essentially a valiant but nonetheless pointless effort. If the scores lose their meaning, it should not impress us that they are more reliable. That being said, it is still true that no score can be considered valid if it is not at least reliable. (p. 372).

To minimize these potential threats, the one-shot case study design method was selected to prevent any changes in the population due to lack of random effects. The results of this study apply only to the population that was studied, and should, in most cases, not be generalized to a larger population or groups in a different setting.

Ethical Procedures

I strived for honesty in all aspects of the research design and implementation. I applied and was approved through our university institutional review board (IRB; #05-29-19-0087361). All data were reported honestly along with results, methods and procedures, and publication status. Objectivity throughout the process was necessary to avoid bias in design, data analysis, data interpretation, and other aspects of the research where objectivity is expected or required (Creswell, 2014). I maintained all agreements made with the participants and was consistent in the experimental design to maintain the integrity of the experiment. The school district maintained meticulous records that were maintained throughout the experimental process to avoid careless errors. I was open to constructive criticism to allow for the implementation of new ideas that were suggested as the research progressed and always had results and resources available for sharing (Creswell, 2014). I protected the confidentiality and was aware of the participants needs and privacy in my the thoughts and design. I protected confidential communication and student identities as this is an integral part of the social responsibility for all researchers. I took special precautions to protect the vulnerable population of students participating in this experiment.

The data did not have student names or have any identifying markers used on the test instrument. The chemoscan cannot be graded for quality as it is solely based on the students creativity. All precautions were taken to prevent any ethical issues to arise. If an issue had arisen I would have resolved the situation by making known the predicament and taken measures to resolve the conflict following the mandates of the ethical standards layed out by Walden University and the participating school district.

To ensure anonymity, the names of students were not recorded. The students that did not complete the survey were not included in the data analysis. The participating school will administer the pre- and posttest TOSRA survey on school issued computers and the data will be stored for 10 years following school district safety procedures.

The chemoscan process began with a one lesson in the first week of the treatment period. The second through sixth chemoscans took 30 minutes per week. The students displayed their chemoscans in a school and community art show after the study was completed. During the last day of the 9-week grading period, the participating students took the posttest in the designated testing area.

The school district provided all necessary procedures to ensure measures had been taken to minimize the risk of loss of privacy, distress, psychological harm, economic loss, damage to professional reputation, and physical harm. They also managed the risk of potential conflicts of interest because the school administered the surveys and collected the data. A third party test administrator provided by the school district administered the test to participants. The test administrator collect all data and is maintained in a secure data format on the district server. The data will be archived until the student for 10 years after administration of the test. No use of identifiers reduced the risk of a privacy so even if a breach occurs participants could not be identified. All demographic information were withheld to protect participants from indirect privacy breaches.

I took precautions to reduce any potential psychological risk such as students being aware of each others answers. Students were not be allowed to move around the room during the test. The tests were given online to ensure privacy.

Relationship risk also existed in the teachers training process as I trained the participating teachers in the chemoscan process. The activity was completed weekly by the teachers which used a lot of their classroom time. I did not help students with the process so researcher trained substitute teachers were available to help when needed to help alleviate teacher workload.

The materials used during the chemoscan process caused minimal risk to the participant and was clearly delineated by the instructor during the instruction process. All typical safety procedures used in a high school classroom laboratory were followed to prevent injuries of any type. The participating school district has waivers on file for all students that participated in district testing. No medical, educational, or business records were used to identify participants. The pre- and posttest were implemented on scheduled test dates set aside by the school district. The researcher has completed certification in the National Institutes of Health training course concerning the protection of human research participants.

Summary

In summary, Chapter 3 included a through description of the research design. The chapter begins with an introduction to the research design which includes research questions that drove the study. Outlined in the next section is the setting and sample of the study, the population to be used and methods of data collection and analysis. In the instrument section I described and justified the instrument used in the study while the preparation of data section describes the methods used to prepare the data for analysis. The data analysis section provides an in-depth interpretation, analysis, and synthesis of the results/findings. I also discussed the limitations and delimitations of the study and the scope of the study. Chapter 3 ended with a look at researcher ethics and the ethical considerations pertaining to participants.

In Chapter 4, I will discuss the results of the analysis of data. The analysis in Chapter 4 also includes answers to the research questions and hypotheses will be discussed. A summary of the outcomes of the analyses will be shared.

Chapter 4: Results

Introduction

The problem under study was that it is unknown whether the activity of creating digital art influences high school students' attitude toward science. To address this purpose, I examined ninth grade physical science students' attitudes toward science after participating in the creation of chemoscans in their science classroom. I compared pre- and posttest scores from the TOSRA, controlling for only those students that had made chemoscans in the ninth grade physical science classroom.

In this chapter, I provide an overview of the data collection process and the intervention fidelity of the study. The research questions that guided this study were:

RQ1: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the social implications of science.

RQ 2: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the normality of scientists.

RQ3: The creation of chemoscans in the physical science classroom will improve students' attitudes toward a career interest in science.

RQ 4: The creation of chemoscans in the physical science classroom will improve students' attitudes toward scientific inquiry.

RQ 5: The creation of chemoscans in the physical science classroom will improve students' attitudes toward the adoption of scientific attitudes.

RQ 6: The creation of chemoscans in the physical science classroom will improve students’ attitudes toward the enjoyment of science lessons.

RQ 7: The creation of chemoscans in the physical science classroom will improve students’ attitudes toward the leisure interest in science.

In this chapter, I share the results of this naturalistic, quasi-experimental, quantitative study. The chapter includes a description of how the data were collected and analyzed as well as the results.

Data Collection

Data were collected by the participating school district in the spring semester of 2019. I gained access to the archival data via the school district coordinator on June 1, 2019. The pretest was given at the beginning of a 9-week grading period, and the posttest was given at the end of the 9-week grading period. The procedures for data collection went as described in Chapter 3. The data provided, included ninth grade students from four high school physical science classes. The response rate was 100% on the pretest with 117 responses. The response rate for the posttest was 93% with 109 responses. The results for students that did not take the posttest were disregarded, which left 109 data sets for analysis. The demographic characteristics of the sample were not provided to protect participants from indirect privacy breaches. The study was completed in a rural high school, a context which may not provide generalizable results to students in suburban and urban populations. Participants were limited to ninth grade students; therefore, the results may be limited in their applicability to students in other grades. The ages of the students were 14 and 15 years old. Informed consent was not required because this was routine school business and I was given access to existing district data. In compliance with Walden University research policy, I met the IRB guidelines before collecting any archival data from the participating school district.

The target population was ninth grade students participating in physical science classes in one rural high school. The sample size was 116 students from four physical science classes with four different teachers. Although the number of classes were lower than provided in Chapter 3, the sample size remained somewhat consistent. The four classes of physical science each had a different teacher and they were each coded with a teacher code to allow for analysis of teacher effect. The class sizes were increased due to new policies in the school district. The limitations in acquiring a convenience sample of students necessitated the use of the quasi-experimental method in this study. It was considered a convenience sample because the class assignments were not random and came from only one school in a rural school district.

Results

I used archival data of 109 ninth grade students in the analysis for this study. The archival data included scores of the TOSRA, both pre- and posttest. Half the students (*n* = 55) received the usual classroom instruction (i.e., the control group), while the other half (*n* = 54) received instruction that included the creation of chemoscans (i.e., the treatment group).

Preliminary Analysis

Prior to conducting the analyses to test the hypotheses, I assessed the subscales of the TOSRA for normality using *z* scores formed by dividing skewness by the standard error of skewness. Values within +/- 3.29 are indicative of normality in sample sizes between 50 and 300 (West, Finch, & Curran, 1995). Table 3 summarizes the statistics for the subscales. Results of basic univariate analysis show that the *z* scores were all well within the range, indicating that the subscale scores were normally distributed.

Table 3

Summary Statistics for TOSRA Subscales

TOSRA subscales	*M*	*SD*	*Skewness*	*SE*	*z*
Pretest					
Social Implications of Science	33.20	6.08	-0.24	0.23	-1.04
Normality of Scientists	30.45	3.50	0.03	0.23	0.13
Career Interest in Science	27.87	6.61	0.14	0.23	0.61
Attitude to Scientific Inquiry	36.20	6.55	-0.22	0.23	-0.95
Adoption of Scientific Attitudes	34.21	5.33	0.26	0.23	1.14
Enjoyment of Science Lessons	30.04	7.30	-0.22	0.23	-0.97
Leisure Interest in Science	27.02	6.37	0.06	0.23	0.25
Posttest					
Social Implications of Science	34.06	4.90	-0.35	0.23	-1.50
Normality of Scientists	31.73	3.78	0.47	0.23	2.05
Career Interest in Science	29.57	6.14	-0.32	0.23	-1.39
Attitude to Scientific Inquiry	36.94	5.81	-0.14	0.23	-0.61
Adoption of Scientific Attitudes	34.72	5.54	-0.31	0.23	-1.32
Enjoyment of Science Lessons	32.84	6.79	-0.72	0.23	-3.12
Leisure Interest in Science	27.31	6.67	-0.01	0.23	-0.05

Hypothesis Testing

The hypotheses were tested against the RQ which included the seven subscales of the TOSRA. Each RQ depicts a different subset of the TOSRA and whether or not the null hypothesis failed or did not fail to be rejected. The data included with each RQ explains whether the null hypothesis failed to be rejected or not.

RQ1: the creation of chemoscans in the physical science classroom will improve students' attitudes toward the social implications of science. This was tested using a group (i.e., treatment vs. control) by repeated measures (i.e., pretest vs. posttest) analysis of variance on the Social Implications of Science subscale of the TOSRA. The results are presented in Table 4.

Table 4

Treatment vs Control on Improvement in Attitudes Toward the Social Implications of Science

		Pretest		Posttest		Analysis of variance				
Group	*N*	*M*	*SD*	*M*	*SD*	*Source*	*F*	*df*	*p*	η^2
Treatment	54	33.09	6.93	34.43	4.55	Pre Post	1.20	1, 107	0.276	0.011
Control	55	33.31	5.17	33.69	5.23	Group	0.13	1, 107	0.718	0.001
						Pre Post * Group	0.37	1, 107	0.545	0.003

The test of the repeated measure (i.e., pre-posttest) indicated no significant change in the students' attitudes toward the social implications of science overall (*F* (1,107) = 1.20, *p* = 0.276). Averaging across the pre- and posttests, I found no significant difference in attitudes between the treatment and control groups (*F* (1,107) = 0.13, *p* = 0.718). The repeated measure (i.e., pre- posttest) by group interaction effect was also not significant, indicating that the creation of the chemoscans had not improved students' attitudes toward the social implications of science (*F* (1,107) = 0.37, *p* = 0.545). Therefore, this data failed to reject null hypothesis.

RQ2 was, the creation of chemoscans in the physical science classroom will improve students' attitudes toward the normality of scientists. This was tested using a group (i.e., treatment vs. control) by repeated measures (i.e., pre- posttest) analysis of variance on the Normality of Scientists subscale of the TOSRA. The results are presented in Table 5.

Table 5

Treatment vs Control on Improvement in Attitudes Toward the Normality of Scientists

		Pretest		Posttest		Analysis of variance				
Group	*N*	*M*	*SD*	*M*	*SD*	*Source*	*F*	*df*	*p*	η^2
Treatment	54	30.37	3.86	33.02	4.12	Pre Post	7.55	1, 107	0.007	0.066
Control	55	30.53	3.14	30.47	2.92	Group	6.01	1, 107	0.016	0.053
						Pre Post * Group	8.19	1, 107	0.005	0.071

The test of the repeated measure (i.e., pre- posttest) indicated a significant improvement in the students' attitudes toward the normality of scientists for all students (*F* (1,107) = 7.55, *p* = 0.007). In addition, I found a significant difference between the treatment and control groups, averaging across the pre- and posttests (*F* (1,107) = 6.01, *p* = 0.016) when looking at the subscale of normality of scientists (*F* (1,107) = 8.19, *p* = 0.005). The partial eta squared (η^2= 0.07) denotes a medium effect. These results support rejection of the null hypothesis and acceptance of the alternative hypothesis. Further illustration of the interaction effect is provided in Figure 1.

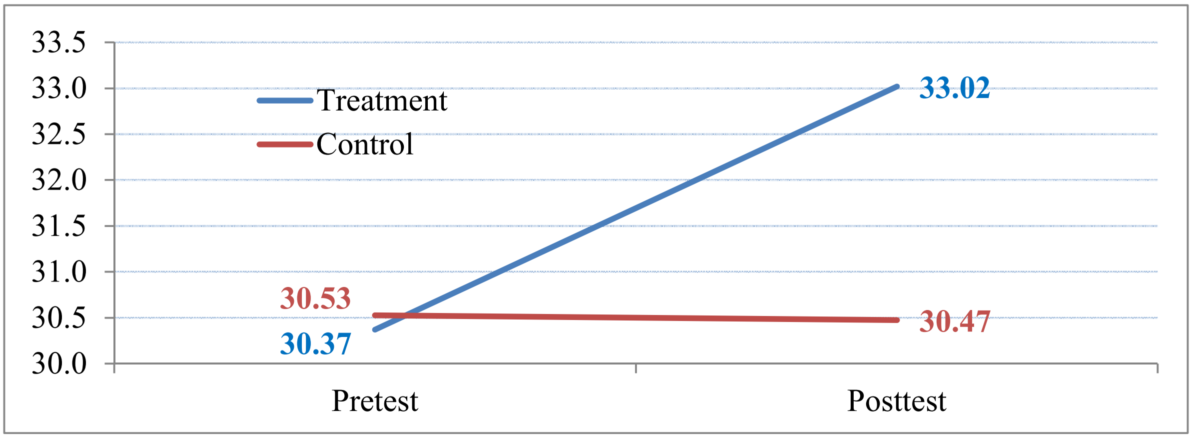

Figure 1. Improvement in attitudes toward the normality of scientists after the creation of chemoscans

RQ3 was, the creation of chemoscans in the physical science classroom will improve students' attitudes toward a career interest in science. This was tested using a group (i.e., treatment vs. control) by repeated measures (i.e., pre- posttest) analysis of variance on the Career Interest in Science subscale of the TOSRA. The results are presented in Table 6.

Table 6

Treatment vs Control on Improvement in Attitudes Toward a Career Interest in Science

		Pretest		Posttest		Analysis of variance				
Group	*N*	*M*	*SD*	*M*	*SD*	*Source*	*F*	*df*	*p*	η^2
Treatment	54	27.37	5.48	30.57	4.57	Pre-Post	4.31	1, 107	0.040	0.039
Control	55	28.36	7.58	28.58	7.28	Group	0.31	1, 107	0.579	0.003
						Pre Post * Group	3.28	1, 107	0.073	0.030

The test of the repeated measure (i.e., pre-posttest) indicated a significant change in attitudes toward a career interest in science for all the students, regardless of whether they had created the chemoscans (*F* (1,107) = 4.31, *p* = 0.040). Averaging across the pre- and posttests, I found no significant difference in attitudes between the treatment and control groups (*F* (1,107) = 0.31, *p* = 0.579). The repeated measure (i.e., pre-posttest) by group interaction effect was also not significant, indicating that the creation of the chemoscans had not improved students' attitudes toward a career interest in science (*F* (1,107) = 3.28, *p* = 0.073). Therefore, the test failed to reject the null hypothesis.

RQ4 was, the creation of chemoscans in the physical science classroom will improve students' attitudes toward scientific inquiry. I tested this hypothesis using a group (i.e., treatment vs. control) by repeated measures (i.e., pre- posttest) analysis of variance on the Attitude to Scientific Inquiry subscale of the TOSRA. The results are presented in Table 7.

Table 7

Treatment vs Control on Improvement in Attitudes Toward Scientific Inquiry

		Pretest		Posttest			Analysis of variance			
Group	*N*	*M*	*SD*	*M*	*SD*	*Source*	*F*	*df*	*p*	η^2
Treatment	54	36.0	6.66	36.02	4.66	Pre-Post	0.80	1, 107	0.374	0.007
Control	55	36.4	6.50	37.84	6.67	Group	1.66	1, 107	0.200	0.015
						Pre-Post * Group	0.76	1, 107	0.386	0.007

The test of the repeated measure (i.e., pre- posttest) indicated no significant change in the students' attitudes toward scientific inquiry overall (*F* (1,107) = 0.80, *p* = 0.374). Averaging across the pre- and posttests, I found no significant difference in attitudes between the treatment and control groups (*F* (1,107) = 1.66, *p* = 0.200). The repeated measure (i.e., pre- posttest) by group interaction effect was also not significant, indicating that the creation of the chemoscans had not improved students' attitudes toward scientific inquiry (*F* (1,107) = 0.76, *p* = 0.386). Therefore, this failed to reject the null hypothesis.

RQ5 was, the creation of chemoscans in the physical science classroom will improve students' attitudes toward the adoption of scientific attitudes. I tested this using a group (i.e., treatment vs. control) by repeated measures (i.e., pre- vs. posttest) analysis of variance on the Adoption of Scientific Attitudes subscale of the TOSRA. The results are presented in Table 8.

Table 8

Treatment vs Control on Improvement in Attitudes Toward the Adoption of Scientific Attitudes

		Pretest		Posttest		Analysis of variance				
Group	*N*	*M*	*SD*	*M*	*SD*	*Source*	*F*	*df*	*p*	η^2
Treatment	54	34.00	5.45	34.59	5.32	Pre Post	0.43	1, 107	0.512	0.004
Control	55	34.42	5.26	34.84	5.79	Group	0.22	1, 107	0.642	0.002
						Pre Post * Group	0.01	1, 107	0.910	0.000

The test of the repeated measure (i.e., pre- posttest) indicated no significant change in the students' attitudes toward the adoption of scientific attitudes overall (*F* (1,107) = 0.43, *p* = 0.512). Averaging across the pre- and posttests, I found no significant difference in attitudes between the treatment and control groups (*F* (1,107) = 0.22, *p* = 0.642). The repeated measure (i.e., pre- posttest) by group interaction effect was also not significant, indicating that the creation of the chemoscans had not improved students' attitudes toward the adoption of scientific attitudes (*F* (1,107) = 0.01, *p* = 0.910). Therefore, this failed to reject the null hypothesis.

RQ6 was, the creation of chemoscans in the physical science classroom will improve students' attitudes toward the enjoyment of science lessons. I tested this hypothesis using a group (i.e., treatment vs. control) by repeated measures (i.e., pre-posttest) analysis of variance on the Enjoyment of Science Lessons subscale of the TOSRA. The results are presented in Table 9.

Table 9

Treatment vs Control on Improvement in Attitudes Toward the Enjoyment of Science Lessons

		Pretest		Posttest		Analysis of variance				
Group	*N*	*M*	*SD*	*M*	*SD*	*Source*	*F*	*df*	*p*	η^2
Treatment	54	29.70	6.55	34.04	5.19	Pre-Post	7.58	1, 107	0.007	0.066
Control	55	30.36	8.01	31.67	7.93	Group	0.95	1, 107	0.331	0.009
						Pre Post * Group	2.18	1, 107	0.143	0.020

The test of the repeated measure (i.e., pre- posttest) indicated a significant change in all the students' attitudes toward the enjoyment of science lessons, regardless of whether or not they had created the chemoscans (*F* (1,107) = 7.58, *p* = 0.007). Averaging across the pre- and posttests, no significant difference in attitudes was found between the treatment and control groups (*F* (1,107) = 0.95, *p* = 0.331). The repeated measure (i.e., pre- posttest) by group interaction effect was also not significant, indicating that the creation of the chemoscans had not improved students' attitudes toward the enjoyment of science lessons (*F* (1,107) = 2.18, *p* = 0.143). Therefore, this failed to reject the null hypothesis.

RQ7 was, the creation of chemoscans in the physical science classroom will improve students' attitudes toward the leisure interest in science. This was tested using a group (treatment vs. control) by repeated measures (i.e., pre- posttest) analysis of variance on the Leisure Interest in Science subscale of the TOSRA. The results are presented in Table 10.

Table 10

Treatment vs Control on Improvement in Attitudes Toward the Leisure Interest in Science

		Pretest		Posttest		Analysis of variance				
Group	*N*	*M*	*SD*	*M*	*SD*	*Source*	*F*	*df*	*p*	η^2
Treatment	54	27.07	6.14	28.48	4.92	Pre Post	0.12	1, 107	0.733	0.001
Control	55	26.96	6.65	26.16	7.92	Group	1.93	1, 107	0.167	0.018
						Pre Post * Group	1.54	1, 107	0.217	0.014

The test of the repeated measure (i.e., pre- posttest) indicated no significant change in the students' attitudes toward the leisure interest in science overall (*F* (1,107) = 0.12, *p* = 0.733). Averaging across the pre- and posttests, no significant difference in attitudes was found between the Treatment and Control groups (*F* (1,107) = 1.93, *p* = 0.167). The repeated measure (i.e., pre- posttest) by group interaction effect was also not significant, indicating that the creation of the chemoscans had not improved students' attitudes toward the leisure interest in science (*F* (1,107) = 1.54, *p* = 0.217). Therefore, this failed to reject the null hypothesis.

Exploratory Analysis

One-way analyses of variance were conducted to determine if there were differences in the amount of improvement experienced by students between the four teachers who conducted the classes during the study period. The dependent variables for these analyses consisted of gain scores, computed by subtracting the pretest scores from the posttest scores for each subscale of the TOSRA. Teachers 3 and 4 taught classes using the chemoscans, while Teachers 1 and 2 taught classes in the traditional manner. The treatment and control conditions were intentionally ignored so that differences between teachers within and across conditions would be treated equally. The results of the ANOVAs are presented in Table 11.

Table 11

Teacher Effects on Improvement in Attitudes Toward Science

	Control				Treatment						
	Teacher 1 (*n* = 28)		Teacher 2 (*n* = 27)		Teacher 3 (*n* = 29)		Teacher 4 (*n* = 25)				
Gain Scores	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	*Post Hoc*
Social Implications of Science	-0.21	6.54	1.00	7.91	-2.31	9.29	5.56	6.79	4.87	0.003	T4> T1, T3
Normality of Scientists	0.07	4.35	-0.19	4.34	-0.10	5.51	5.84	3.37	11.11	< .001	T4 > T1, T2, T3
Attitude toward Scientific Inquiry	8.54	9.52	13.30	9.48	6.48	7.43	11.80	7.04	3.69	0.014	T2 > T3
Adoption of Scientific Attitudes	-0.71	7.90	1.59	8.44	-2.03	7.01	3.64	7.77	2.79	0.044	
Enjoyment of Science Lessons	-2.82	11.59	5.59	11.73	1.76	8.38	7.32	8.41	5.28	0.002	T2, T4 > T1
Leisure Interest in Science	-1.46	11.83	-0.11	10.56	0.07	7.11	2.96	6.42	1.04	0.378	
Career Interest in Science	-0.21	9.43	0.67	11.14	1.52	6.57	5.16	6.14	1.95	0.126	

As shown, teacher effects were found for five of the seven TOSRA subscales. Post hoc pairwise comparisons with Bonferroni adjustments were conducted to determine the source of the significant differences; in other words, which teachers had students who improved more than which other teachers. The students in Teacher 4's classroom improved more in their attitudes toward the social implications of science compared to students taught by Teachers 1 and 3 (*F* (3, 108) = 4.87, *p* = .003; Bonferroni *p* < .05). The students in Teacher 4's classroom also improved significantly more in their attitudes toward the normality of scientists compared to students taught by all other teachers (*F* (3,

108) = 11.11, $p < .001$; Bonferroni $p < .05$). The students in Teacher 2's classroom improved significantly more in their attitudes toward scientific inquiry compared to students taught by Teacher 3 (F (3, 108) = 3.69, $p = .014$; Bonferroni $p < .05$). Although there was a significant teacher effect found for the Adoption of Scientific Attitudes scale (F (3, 108) = 2.79, $p = .044$), none of the post hoc tests revealed significant pairwise differences. Finally, the students of both Teachers 2 and 4 improved significantly more in their enjoyment of science lessons compared to students taught by Teacher 1 (F (3, 108) = 5.28, $p = .002$; Bonferroni $p < .05$). These results indicate that the teacher effect was not simply a function whether the chemoscans were used in the classroom, since differences in improvement were found between and across conditions. Both Teacher 3 and 4 used the chemoscans, but Teacher 4's students improved significantly more than students of Teacher 3 in some cases. Also, Teacher 2's students, who did not have the experience of creating the chemoscans, improved significantly more in their attitudes toward scientific inquiry compared to students of Teacher 3, who did create chemoscans in their classroom.

Summary

There were three key findings to this study. The first key finding was that the creation of artistic digital chemoscans impacted high school physical science students' attitude toward science related to the normality of scientists, if administered by a talented teacher. The second key finding was the creation of artistic digital chemoscans by physical science high school students did not impact students' attitudes toward science related to social implications of science, attitude to scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science. The third key finding was a large teacher effect in this study indicated that students' attitude toward science, as measured by the TOSRA, was influenced by the teacher, independent of whether or not students created Chemoscans.

In Chapter 5 the interpretation of the study data and the limitations of the study will be addressed. Chapter 5 also includes further discussions, recommendations, and implications of the use of art and technology to increase student interest in science. The subjects of positive social change, and instructional practices relative to findings are also presented in chapter 5.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The problem under study was that it is unknown whether the activity of creating digital art influences high school students' attitude toward science. The purpose of this naturalistic, quasi-experimental study was to determine if the creation of artistic digital chemoscans by high school students influences their attitude toward science. Chemoscans are digital images of a chemical reaction as it occurs. After making a chemoscan, students then modify it in photo-editing software programs to create a scientific artistic piece (Ezell & Case, 2017). To accomplish the purpose of this study, I used archival data from pre- and posttests on scientific attitudes completed by ninth grade physical science students in a rural southeast school district in the United States. The comparison groups were students that did not create chemoscans and students that did create chemoscans, but both were otherwise similar in student profile and physical science class level.

There were three key findings of this study. The first key finding was that the creation of artistic digital chemoscans impacted high school physical science students' attitude toward science related to the normality of scientists, if administered by a talented teacher. The second key finding was that the creation of artistic digital chemoscans by physical science high school students did not impact students' attitudes toward science related to social implications of science, attitude to scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science. The third key finding was that a large teacher effect in this study indicated that students' attitude toward science, as measured by the TOSRA, was influenced by the teacher, independent of whether students created chemoscans. In this chapter, I discuss my interpretation of the findings, nonsignificant changes in attitude toward changes, teacher effect, limitations of the study, recommendations, and implications of this study.

Interpretation of the Findings

In this section, I interpret the results of this study organized by the key findings. I first discuss the results related to students' attitudes toward the normality of scientists and how it differs from the other 7 subscales from the RQ. I then interpret what the nonsignificant results may mean and end the section with a discussion of the teacher effect.

Normality of Scientists

The first key finding of this study was that the creation of artistic digital chemoscans impacted high school physical science students' attitude toward science related to the normality of scientists, if administered by a talented teacher. Attitudes related to the normality of scientists have been shown to change in elementary students (Toma, Greca, & Orozco, 2019), middle school students (Tretter, Ardasheva, Morrison, & Roo, 2019), and preservice teachers (Gürgil, 2018), and the results from this study show that attitudes can also change in high school students. Changes in attitudes toward the normality of scientists have been shown after summer-long STEM experiences (Han, Capraro, & Capraro, 2015), but the findings of the current study extend the literature to show that maybe lessons integrated into the traditional science classroom can influence high school students related to how they view scientists.

In this study, only Teacher 4's students improved substantially in their attitudes concerning the normality of scientists, so they could have carried the effect for all the students in the treatment condition. The analysis demonstrated that making chemoscans in the science classroom did not have large effect on students' attitude toward science, but it did have some effect on the way students looked at the normality of scientists. There was a failure to reject the null hypothesis for 6 of the 7 RQ. There is no way to tell for sure, since there was no crossover between teachers and treatment/control. Regardless, the results of this study may show that attitude regarding the normality of scientists is worthy of continued study. Other studies that include art into the learning experience have been shown to influence how students view scientists. Ness (2015) found that many students do not associate science with creativity. It is possible that the art activity in this study, chemoscans, helped students see creativity as part of science and may have influenced their view of scientists.

Nonsignificant Changes in Attitudes Toward Science

The second key finding was that the creation of artistic digital chemoscans by high school physical science students did not impact students' attitudes toward science related to social implications of science, attitude toward scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, or career interest in science. There are several interpretations for the nonsignificant results of this study. First, the quantitative study design of this research was limited by what the

TOSRA instrument measured and may not have captured how participants may have changed their attitude toward science. A qualitative research approach might help explore how, if at all, creating chemoscans influenced students' experiences in science class. A qualitative study may enable researchers to understand how students feel about their experiences when creating chemoscans, enabling a researcher to understand more fully if the treatment affected the students' attitudes.

Second, the interpretation for the nonsignificant results could be that the TOSRA was not the correct instrument to use for measuring students' attitude after creating chemoscans in the classroom. Along this same line is the possibility that a modified version of the TOSRA without a neutral answer choice could have been a better measure for student attitudes toward science because it would require them to give a positive or negative answer. Kah-Eng and Karpudewan (2017) used a modified form of the TOSRA that eliminated the neutral responses, forcing students to make a positive or negative choice. The researchers used the results solely to determine if students were interested in science or not to help teachers determine how to help them. Additionally, even if attitude toward science is not influenced by chemoscans, it is possible that the digital art activity influenced students in ways not related to attitude toward science and should still be explored.

Teacher Effect

The third key finding was that a large teacher effect in this study indicated that students' attitude toward science, as measured by the TOSRA, was influenced by the teacher independent of whether students created artistic digital chemoscans. Teacher effect influenced several constructs from this study, including social implications of science, normality of science, scientific inquiry, adoption of scientific attitudes, and enjoyment of science lessons. The results of this study may confirm what others have found, that teachers' interpersonal behaviors can affect student attitudes toward science (Çakır & İskar, 2015). This may indicate that the teacher's style and method can affect students' attitudes toward what they are learning as much or more as the activity itself, which could mean that training teachers differently and assessing their enthusiasm toward presenting chemoscans in class could be an effective teaching design method when trying to incorporate new classroom strategies.

All the participating teachers were trained the same way, but all have different teaching styles and levels of enthusiasm when presenting material (see Lazarides, Gaspard, & Dicke, 2019). The way a teacher presented the chemoscan to the students could have had an effect on the lack of significant findings. The lack of significant results in this study could indicate that the participating teachers need more training in the production of chemoscans and how to most effectively implement art activities in the physical science classroom. It is possible that improved teacher training might yield different results. Mitchell (2013) found that teacher enthusiasm can have a profound effect on student motivation, so more teacher training would be needed to help participating teachers feel more comfortable about chemoscan creation.

The teacher's approach to chemoscan production during this study could have been affected by their attitude toward using art in the classroom. All teachers involved in the study were trained the same way, but the training did not include a discussion about the benefits of including art or STEAM activities in the science classroom. Herro and Quigley (2016) explored how teachers make sense of the use of STEAM in the classroom and concluded that many teachers find STEAM activities to be so different from their normal methods of teaching that is takes extra time to implement effectively. The teachers from this study needed time to reflect on the activities in order to refine their methods. The teachers also required a very clear definition of STEAM in order to understand why they were using art when teaching science. This may explain why teacher effect seemed to have so much influence on student attitude.

Limitations of the Study

There were potential limitations associated with the research design used in this study. First, I used convenience sampling to select the participants for this quantitative study, and the sample size was relatively small (*n* = 116) which was underpowered. As a result, the sample was not representative of all school districts in the state and did not allow for enough students to complete the research. The results cannot be generalized to schools that have larger or more diverse populations.

The second limitation concerns the use of different teachers in the treatment and control groups. Considering the large teacher effect found in this study, it would be important to complete further research concerning teacher attitude toward the use of art in the science classroom. There was no overlap between treatment and control groups and each of the teachers (i.e., two were treatment teachers and two were control teachers). To truly test a teacher effect, each teacher would have had to teach half of their class using the chemoscans and half not using Chemoscans can change their minds about science. It may take a teacher that is very enthusiastic or very skilled to help students when creating Chemoscans in order to see an effect.

The third limitation was the treatment time during the study. This study only allowed students a short time period to make a few Chemoscans. To determine if students attitude changed more time with the treatment period to create Chemoscans.

Recommendations

My recommendations for further research are based on study results and limitations of the study. The first recommendation is the instrument used to measure changes in students' attitudes. It is possible that the TOSRA was not the best instrument to use for measuring student attitude after creating chemoscans. Cheung (2009) used an instrument entitled, Attitude Toward Chemistry Lessons Scale, to measure male versus female interest in chemistry lessons. This type of scale could be a better measure for a research study concerning chemoscan creation because the survey is chemistry based. Another instrument entitled the Image of Science and Scientists Scale could be used to more effectively measure student views concerning scientists because it focuses directly on positive and negative images of scientists as well as science avocation (see Marshall, Blalock, & Liu, 2007).

My second recommendation for further research is related to the methodology. Instead of using the quantitative method, future researchers could take a qualitative approach. The use of interviews, journaling, and artist reflection might allow students to better describe their experiences during the treatment. Since using digital art in science could be considered a creative and personal process, interviews and journaling could be a better measurement of student attitudes and allow the researcher deeper insight into what the students experienced.

The third recommendation is to explore science teachers' perceptions of the use of art in the science classroom. Understanding how teachers feel about the process can help researchers design a study that effectively measures student attitudes and the factors that can affect them. A longitudinal study to determine teacher attitudes toward art in the science classroom could be an important factor to help with further research design.

My last recommendation is related to the limitations of this study. I conducted this study with 116 ninth grade students at a rural high school in the southeastern United States. This number of participants was the bare minimum for the calculated power; therefore, this study should be replicated in various high school settings with a larger sample size to determine if results are similar.

Implications

The findings of this study may contribute to positive social change in several ways. First, at the individual level, teachers consistently need more innovative lessons to help increase student interest in science. The use of digital artistic images can be one method to help teachers in the classroom. There is also potential for change at the organizational level because school districts are always looking for methods to help teachers in the classroom that leads to students wanting to learn more about any subject. The results of this study could advance research concerning how to measure student attitudes toward science when using digital art in the science classroom to increase interest in science. This could advance knowledge in the field of educational technology.

There is also the potential for the findings of this study to advance knowledge of how digital art technologies might help improve students' attitudes toward science. The results of the study could promote more studies that help the understanding of how digital art can improve students' attitude in the classroom.

This study also has potential implications for positive social change. The lack of significant findings does not diminish the need to discover how art and technology can be used to improve classroom teaching methods. The study of chemoscan creation using different experimental methods could lead to improved understanding of how technological tools might be used to improve students' attitudes in science. This could lead to improved classroom practice, possibly improving student interest in pursuing STEM-based careers in the future.

Conclusion

If educators are to effectively prepare their students for successful lives in the 21st century, then students should have the opportunity to learn technologies that help them have a more positive attitude toward science. Although the tools are currently available, they are not being used in schools to the degree they should be. An opportunity to enrich the quality of students' learning through the use of technology and art needs to be explored.

In this study, I focused on the use of chemoscans to increase student interest in science. Bloom et al.'s (1956) theory of affective domain was used as a lens through which to understand why creating digital art could increase students' interest. By understanding this type of activity and its effect on students, teachers could be provided with a variety of methods to help students achieve a real love of learning.

The need for technology-based educational activities is on the rise as schools become more focused on developing 21st century skills. In this study, I attempted to create an opportunity for teachers using educational technology to share insight and identify methods to use new technology-based lessons in the classroom. Although the results did not show significant change in students' science attitudes, it could become the beginning of understanding how digital art can make the difference for students' attitudes towards science in the future.

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Appendix A: Chemoscan Lesson Plan

Lesson Plan Chemoscan Creation
Grade/Grade Band: 9
Topic: Chemical Reactions

Performance Expectation(s): HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

Specific Learning Outcomes: Scientific knowledge assumes that natural laws operate today as they did in the past and they will continue to do so in the future.

Narrative / Background Information
Prior Student Knowledge:
Atomic structure and nuclear processes
Bonding and chemical formulas
Types of chemical reactions

Science & Engineering Practices:
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs. Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

- CoreETS1.B: Developing Possible Solutions
  - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)
- PS1.B: Chemical Reactions
  - The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.
- PS1.A: Structure and Properties of Matter
  - The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. Ideas:
- Crosscutting Concepts:
  - Patterns
  - Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena (HS.LS1.C ; HS.ESS2.C)

Possible Preconceptions/Misconceptions:
Understanding the difference between chemical and physical reactions
Understanding what the key components of a reaction versus the spectators
Understanding that different elements react different ways

LESSON PLAN – 5-E Model
ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:
The students will be given previously created chemoscans to view and discuss in groups. The students will be asked to determine what they think they are looking at in each image and evaluate its aesthetic appeal. If no chemoscans are available go to http://fineartamerica.com/art/chemistry for examples of chemistry-based art.

Students should answer these questions:

What is art?
How does art fit into the science realm?
How are these images based in chemistry?
How could we use a chemistry concept we have learned to create art?

The students will report their findings in a whole class discussion.
The timing listed below is a suggestion only. The teacher may do all the work in one class.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:
Day 1 and 2 activities will not take the entire period so other work can take place (review, research, etc.)
Suggested format
Day 1

- Opening Activity
- Whole class discussion -chemoscans a digitized image of a chemical reaction as it occurs
- Review chemical reaction types
- Students will be tasked with researching possible materials for their chemical reaction at home. They will bring in a list of possible materials for day 2

Day 2 Individual work

- Students will work individually and look over their lists of materials from home
- The student should decide what they think will be a viable chemical reaction and what will not be based on prior knowledge.
- Each student is required to design a unique reaction for their chemoscan. For instance, one individual may use tums and vinegar, another individual may design banana and hydrogen peroxide, and may use ketchup and vinegar. The students

will write the formula for the chemical reaction they have chosen and predict the outcome of the product.

- The student chemical product prediction will be shown to the teacher for approval. Once approval has been given from the teacher the chemoscan process will begin. Time needs to be provided for the individual student to work on their completed chemoscan in Photoshop (if available) or https://pixlr.com/ (free). The students will complete an artist statement to include with the artwork when displayed (see elaborate).

Chemoscan Creation

The student will place a glass or plastic petri dish with no lid on an open scanner. The student will quickly place the reactants from his reaction design on the plate and close the scanner as much as possible while hitting the scan button. It is important that the student get the image scanned as the reaction takes place (the chemoscan process may take more than one day depending on the number of students involved). The students may also use their phone camera or a digital camera if available.

**The chemoscan must be saved to be imported into a photo editor at a later time.*

EXPLAIN: Concepts Explained and Vocabulary Defined:

Chemoscan
Chemical reaction
Reactants and products
Acid Base reaction
Single displacement reaction
Double replacement reaction
Synthesis reaction
Combustion
Precipitate

ELABORATE: Applications and Extensions:

The students will complete an artist statement that includes the questions:

What did I do?
How did I do it?
Why did I do it this way?
What influenced me most?
What do I want others to understand about my art?
What was the reaction? Include formula
Explain what is happening in the reaction.

EVALUATE:

Formative Monitoring (Questioning/Discussion):
Summative Assessment: Artist Statement and Art Show Display

Elaborate Further/Reflect: Enrichment

The students can enter their work into a photography contest they find locally or on the internet if they so choose. The students can create a different type of chemoscan based on a science concept they have learned in class but not necessarily a chemical reaction; for example, polarized light, chromatography, surface tension, etc.

Appendix B: Permission to Use the TOSRA

Deborah

You are welcome to modify, translate and use TOSRA in your research.

Good luck.

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