EFFECTIVE MULTIMODAL TEXTS TO BE IMPLEMENTED IN SECONDARY SCIENCE CLASSROOMS

by

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CERTIFICATION OF THESIS/PROJECT CAPSTONE WORK

We, the undersigned, certify that this project entitled Effective Multimodal Texts to be Implemented in Secondary Science Classrooms by Megan Kucharski, Candidate for the Degree of Master of Science in Education, Literacy Birth to Grade 12, is acceptable in form and content and demonstrates a satisfactory knowledge of the field covered by this project.

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ABSTRACT

There has been an abundant amount of multimodal texts in which high school science teachers were able to use throughout their instruction to communicate science content. The problem related to this topic was high school science teachers were either not using them or not using them appropriately. The question related to the problem of high school science teachers not correctly using multimodal texts was "What are effective multimodal texts that support content comprehension and science literacy and how can these resources be implemented in the secondary science classroom?" To address this question an extensive literature review, research analysis, and research synthesis were completed. The participants of the studies were in a variety of science courses at the middle school, high school or college level. Multiple findings resulted from the research synthesis. The findings were trade books and technology in science classes were effective at both middle and high school levels, primary literature in science classes were effective at the collegiate level, and middle and high school science students benefited from teachers embedding multimodalities in their instruction. The fifth finding was simulations at the high school level enhanced student science literacy. This was the finding that answered the research question. This finding was then used to create a professional development Google Site for high school science teachers of all content areas. The Google Site provided a resource for the teachers to learn about simulations, understand the research behind it, practice using them, and be instructed on how to implement them into science instruction at the high school level.

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Chapter 1: Introduction

Statement of the Problem

The concept of multimodality has begun to make an appearance in the classroom and is more widely accepted in schools (Jacobs, 2012). The use of multimodal texts, specifically powerpoints and websites, when used properly can enhance student learning by "providing meaningful context" to students of all learning levels (Varma, Husic, & Linn, 2008; Bang & Luft, 2013).

Nixon, Smith, and Wimmer (2015) argued that using more than one mode to represent one meaning is the most effective way to communicate more complex ideas within the science content. Jacobs (2012) also agreed with this concept and stated "multimodal texts are rich in literacy practices" allowing students to experience a variety of forms of communication. The author mentioned presenting different forms of communication provides the students an opportunity to think outside the normal thought process when using a "traditional text."

However, Bang and Luft (2013) found that often teachers are using multimodal texts, specifically technology resources, to enhance their teacher-centered lecture methods instead of changing their instructional methods to enhance student learning. These researchers noted that teachers need to be constantly updating their methods of incorporating technology to create a student-centered learning environment to include blogs (to facilitate students discussions), simulations (to connect real life and content knowledge), virtual teams (student collaboration), and role play (connections to real life).

Several authors (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins, Lopatto, & Stevens, 2011) have demonstrated that using primary literature as part of multimodal texts in

science classrooms has promoted improved student research and data analysis skills, increased

critical thinking, and confidence in students when approaching scientific literature. Trade books

are another effective multimodal text that has been proven to increase comprehension, provoke

higher order of thinking, and engage the reader (Fang & Wei, 2010; Heisey & Kucan, 2010;

Chen, Chang, & Yang, 2017; Smolkin, McTigue, Donovan, & Coleman, 2009).

The problem related to this topic is that in secondary science classrooms, students have

not been exposed to a multimodal environment to support their analytical and critical thinking

skills. This lack of a multimodal environment leads to the question: What are effective

multimodal texts that support content comprehension and science literacy and how can these

resources be implemented in the secondary science classroom? The most appropriate way to

address the question of the effective multimodal texts in the science classroom is by conducting

an extensive literature review, synthesizing the findings, and creating a professional development

project to improve the practices of literacy specialists.

Background

The development of this question stems from personal experiences and curiosity. When I

was a student in secondary science, I recall many of my science classes being taught with a

teacher-centered lecture format. We used one textbook for both lecture and lab and that was as

far as our resources went. I am now certified in biology grades 7-12 and have had the pleasure

of subbing in science classrooms at the secondary level. The majority of the classrooms I have

been in use the same lecture and science textbook. As a literacy specialist, I am aware of the

importance of having a multimodal, multilevel classroom to give students access to as many

forms of the content as possible.

The research question started off more broad, I wanted to find a way to incorporate both my science certification and my literacy specialist certification. The literacy portion of the question began with my curiosity of what, as a literacy specialist, can I recommend to science teachers to create a science literacy environment for their students.

Terminology

There were key terms which were used in this proposal and may require clarification. The first term was multimodality, which refers to an approach in education where different forms of communication are utilized at the same time, such as data charts with an article, in order to provide a more meaningful delivery of the content knowledge (Jacobs, 2012). Jacobs (2012) also defined the term multimodal text as the various forms to communicate the content such as picture books, newspapers, magazines, informational books, digital texts, games, videos, and podcasts. The texts can be visual, written, auditory or spatial (dance or performance).

Another term that required clarification was dynamic visualizations (DV). According to researchers (Chiu & Linn, 2013; Chang, Zhang, & Chang, 2014), DV were models created using a computer program to enhance student understanding of concepts they may not be able to see or witness in real-life.

The next term was Web-Based Inquiry Science Environment (WISE) which was a computer program used by teachers and researchers to create or adapt curricula for their science classroom to increase science inquiry and assess students throughout a unit. The WISE program is free, research based, and is a great resource for science teachers by providing an array of tools to guide students through inquiry, reflection, and assessments. (Chiu & Linn, 2013; Chang et al., 2014).

Another term in need of clarification was Knowledge Integration (KI). Multiple researchers (Chao, Chiu, DeJaegher, & Pan, 2015; Chiu & Linn, 2013) have defined KI as using student's previous knowledge and experiences to enhance their experiences with new knowledge. To integrate knowledge properly a teacher should provide opportunities for students to take a look at their real life experiences through experiments, instructional strategies, and discussions.

Another term defined by Suardana, Redhana, Sudiatmika, and Selamat (2018) was the 7E learning model. These authors referred to an instructional approach in science classrooms that has been proven to be an effective method to increase students' critical thinking by activating students prior knowledge (*elicitation*), motivating them to learn (*engagement*), giving students opportunities to explore science through experimentation (*exploration*), allowing students opportunity to communicate what they have learned throughout the lessons (*explanation*), giving students the opportunity to use what they have learned in other scenarios and in their everyday life making the content more relevant and meaningful (*elaboration and extension*). Students are also assessed at the end of each lesson to demonstrate their content comprehension (*evaluation*).

The last term that required clarification was Trade Books. Smoklin, Mctigue, Donovan, and Coleman (2008) described trade books as books that the general public can access and typically has one author, unlike textbooks that are most likely bought through a school district and created by a publishing company. Trade books can be fiction, non-fiction, picture books, narratives or informative.

Theoretical Stance

The theoretical stance that supports this research was the theory of dual coding theory

(She & Chen, 2009). The dual coding theory provides a link between enhanced learning and the use of two modes of communication such as a visual mode and an auditory mode at the same time. Using multimodality to increase student performance has been demonstrated through multiple studies in this research. Several researchers (Saltan & Divarci, 2017; Yildirim & Sensoy, 2018) have indicated that the use of multiple modalities promotes environmental literacy and found them to be effective in increasing comprehension of the content.

The proposed research synthesis aligned with the International Reading Association (IRA) *Standards for Reading Professionals* (2010). Several of the Standards addressed the component of literacy development and influences on it. For example, this candidate was addressing Standard 2 Curriculum and Instruction by researching appropriate and varied instructional approaches to develop word recognition, comprehension, strategic knowledge, and reading-writing connections.

Rationale

Bang and Luft (2013) found that first year teachers had advanced technology skills but only used technology to conduct their teacher centered lectures or to store and organize data. They concluded that even though technology is prevalent in classrooms it is not necessarily used appropriately when it comes to creating a science literacy environment. The technology being used in this study does not enhance the learning environment.

Bello, Ibi, and Bukar (2016) completed a study where technology was used appropriately to enhance student learning and creating a science literacy environment. The researchers compared the use of simulation techniques and teacher centered lecture to teach science content. The results demonstrated simulation techniques to be more effective than teacher centered

lecture in the area of student comprehension. Simulation techniques is a method that allows

students to experience the topic first hand which in turn students create meaning and their

learning environment is enhanced. This study is an example of how appropriate use of

technology can create a science literacy environment where students can achieve academic

success in science through student engagement and a positive learning experience. (Bello, et al.,

2016).

   The first purpose of this proposed research is to further the growing bank of knowledge

in effective multimodal texts used in science classrooms. The second purpose of this proposed

research is how to implement effective multimodal texts in the science classroom. The research

is important to the field of education because it will contribute knowledge that using multimodal

texts in secondary science classrooms can have a positive impact on student academic

achievement and content comprehension.

Chapter 2: Literature Review

In order to address the research question of effective multimodal resources to support student content comprehension and science literacy, a review of the empirical research studies on the topic was conducted. The literature review began with a search of three major databases ERIC through EBSCO Host, Academic Onefile, and One Search. On the ERIC database, keywords and phrases that were used in the searches included science literacy, science comprehension, science education, literacy, multimodalities in science education, science education and the modes of learning, teacher led instruction, and student led instruction. After finding the most relevant articles on the ERIC database, Academic Onefile was searched using the phrase "Multimodal text in science classrooms." The results provided only a few relevant articles, however, from the work cited lists many relevant research articles were found. The articles were found through searching the work cited titles on the One Search database. The studies most relevant to this proposed research were grouped below by theme and arranged according to the factors they examined.

The Use of Primary Literature in Science Classrooms to Enhance Student Learning

Several authors (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent, Marbach-Ad, Swanson, & Smith, 2010) investigated the use of primary literature in college courses to address students ability to think critically about science. Hoskins and colleagues (2011), as well as, Carter and Wiles (2017) utilized the distinct approach **C**onsider, **R**ead, **E**lucidate hypotheses, **A**nalyze and interpret data, **T**hink of the next **E**xperiment (C.R.E.A.T.E.) alongside primary literature to support student ability to think critically about science. C.R.E.A.T.E. was an approach to learning science literacy in such a way that students

should become more prepared to understand the science content by allowing students to actively

engage in science discussions. This approach was meant to make the content seem more relevant

to students. Students were to read multiple primary articles and then participated in discussions

about the articles in which they discussed them in depth and demonstrated their understanding of

how the research contributes to the broader scope of that topic. The researchers discovered the

C.R.E.A.T.E. approach to reading and analyzing primary literature boosted student confidence in

their science literacy abilities (reading, understanding, explaining science). All of the

researchers (Carter & Wiles, 2017; Hoskins et al., 2011) found the use of primary literature

alongside the C.R.E.A.T.E. approach was proven through this study to be an effective

multimodal strategy.

Although Eslinger and Kent (2018) did not use the C.R.E.A.T.E method (Carter & Wiles,

2017; Hoskins et al., 2011), their method involved enhancing student comprehension through

similar procedures. After reading the primary literature, the students explained the key terms,

the background, and experimental design in their own words. Next, the students analyzed or

summarized a key experimental method through a diagram or flowchart. After analysis, the

students synthesized, in other words they needed to generate a new hypothesis or propose an

additional experiment. Last, the students evaluated or prepared a written or verbal assessment of

the article analysis. The students in the study demonstrated improved scientific literacy and a

higher order of thinking through presentations and assessments.

Similar to the previous researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017;

Hoskins et al., 2011), Parent and colleagues (2010) used the Literature-Based Learning (LBL)

approach to enhance student comprehension of science literacy.   The C.R.E.A.T.E. method was

used by Hoskins and colleagues (2011), as well as, Carter and Wiles (2017), which is similar to the LBL approach Parent and colleagues (2010) used. The authors used research articles to enhance student comprehension by communicating the content in a realistic way and using previously conducted research that directly related to the classroom content. This demonstrated how researchers conducted studies pertaining to the content the students were learning. Parent et al. (2010) used the LBL approach to demonstrate lab techniques the students have been learning throughout the course. The LBL approach began with students reviewing the introduction of a research study which utilized lab techniques the students were currently learning and were to determine an appropriate research question and choose a lab technique that would work in this scenario. During this portion of the LBL approach the students were engaged in a higher order of thinking when analyzing the introduction portion of the research. The students then read and analyzed the rest of the research article focusing on the research question being asked and the lab technique being used.

Similar to other researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011), Parent and colleagues (2010) assessed the students through a presentation of their skills of analyzing research. The students completed an Experimental Design Project(EDP). The EDP gave the students a scenario to which the students then analyzed and designed an experiment that was then completed in real life. Their experiment was then presented through a research report Through post-survey it was determined that students felt more comfortable with reading research articles, gave them a better understanding of completing research, and found the course to be engaging (Parent et al., 2010). The EDP's determined the students to have a greater knowledge of scientific research and methods from the Immunology Lab with the LBL approach

than the Immunology Lab that did not provide research articles as a way to communicate content. Therefore, using research articles in a science laboratory course is an effective way to increase student's science literacy and comprehension (Parent et al., 2010).

Since the primary literature used was mainly research articles, the researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins, et al., 2011; Parent et al., 2010) discovered students were more likely to understand how research in science is completed through exposure to scientific research articles. Exposure to scientific research articles also encouraged students to use metacognitive strategies to assist them in interpreting deeper content. The research also proved to encourage a higher order of thinking. In other words, these studies contribute to the knowledge that primary literature, when used correctly, is an effective multimodal text to encourage students to think critically and further understand the science being taught.

The Use of Trade Books in Science Classrooms to Enhance Student Learning

According to Yacoubian and colleagues (2011), trade books were a tool used to supply students with a richer and more "up-to-date coverage" of content. Unlike classroom textbooks, trade books are able to assist students in taking the content further and connect it to the real world, which can facilitate science inquiry and literacy. Students are more likely to understand the content with the deeper explanations the trade books provide (Yacoubian et al., 2011).

Several authors (Chen et al., 2017; Fang & Wei, 2010; Fang et al., 2008) investigated the use of trade books in secondary science classrooms. These researchers found that the use of trade books in secondary science classrooms was beneficial to student learning. They also noted that science trade books fostered a deeper understanding of the science content. Science trade books contained richer content than classroom textbooks and required the student to think more

critically and analytically about the topic (Fang & Wei, 2010). The students demonstrated their

understanding through assessments that evaluated the students' science content knowledge and

literacy.

The researchers (Chen et al., 2017, Fang & Wei, 2010; Fang et al., 2008) also used

reading programs that encouraged students to read science trade books for pleasure, outside of

the classroom and with their families. Chen and colleagues (2017) focused on high school

students academic achievement after participating in a reading at home program over the course

of three years.

Some researchers (Fang & Wei, 2010; Fang et al., 2008) provided extra support for their

middle school students throughout the reading program. The extra support increased student

readability of the science trade books through explicit instruction of reading strategies.

Specifically, Fang and Wei (2010) explicitly taught students strategies to use during their

reading. The strategies assisted them in increasing their awareness of certain skills needed to

understand content specific trade books. The skills Fang and Wei (2010) discuss are skills

specific to the science content, skills such as "predicting, inferring, monitoring, making

connections, analyzing, drawing conclusions, and problem solving" (Fang & Wei, 2010, p. 267).

The researchers (Chen et al., 2017; Fang & Wei, 2010; Fang et al., 2008) motivated

students to read science trade books, however, their methods to motivate were slightly different.

Fang and Wei (2010) and Fang et al. (2008) used response questions and discussions to drive

student motivation, whereas Chen and colleagues (2017) used a "Reading for Pleasure" program

that rewarded students based on how much they read and scores they received. Students who

were apart of the reading programs demonstrated increased academic achievement on the science

assessments, providing further proof that using trade books is an effective way to deepen content comprehension.

The Use of Technology in Science Classrooms to Enhance Student Learning

A large number of researchers (Saltan & Divarci, 2017; Bello et al., 2016; Yildirim & Sensoy, 2018; Stern, Barnea, & Shauli, 2008; Chao et al., 2015; Chiu & Linn, 2013; Chang et al., 2014; Barab et al., 2009; Birchfield & Megowan-Romanowicz, 2009; Trey & Khan, 2008; Chen & Howard, 2010; Chang, Chen, Lin, & Sung, 2008) have linked an increase in science comprehension and literacy to the implementation of technology into the science classroom. The authors used different technologies to prove a similar result, which is technology increases student knowledge of science content, enhances students' higher order of thinking and allows students to create meaning of the science they are learning.

Saltan and Divarci (2017) specifically studied the use of blog activities in the elementary science classroom and what effect they would have on elementary students' environmental literacy. Environmental literacy is the student's knowledge of, interest in, use of, and attitude towards the environment. Student environmental literacy was measured using the Environmental Literacy Scale which poses seven questions asking the students about their environmental literacy. They also examined the effect of the student's parents interest and involvement in outdoor activities. Saltan and Divarci (2017) found that when involved in blogging activities related to environmental science along with parental involvement students' acquire environmental literacy. They found student knowledge of the environment was increased through blog usage along with improvement of their attitude toward and usage of the environment. This study adds to the bank of knowledge that certain technologies used alongside classroom

instruction increases student's science literacy.

Many researchers (Yildirim & Sensoy, 2018; Bello et al., 2016; Stern et al., 2008; Chao et al., 2015; Chiu & Linn, 2013; Chang et al., 2014; Barab et al., 2009; Birchfield & Megowan-Romanowicz, 2009; Trey & Khan, 2008) used experimental design to determine whether or not technology plays a positive role in science comprehension and literacy. Yildirim and Sensoy (2018) used cartoons, animations, and concept maps during the course introduction; during the developmental stage simulations and experimental activities were completed; during the extension phase there was an increase in reality applications and digital stories; and lastly during the evaluation stage students completed puzzles, concept maps, and exams through virtual classroom applications. Along with Saltan and Divarci (2017), Yildirim and Sensoy (2018) also found that adding technological components to science instruction played a significant role in the increase of science achievement and the increase was sustained six weeks post-experiment for the experimental group and decreased for the control group.

Similar to Yildirim and Sensoy (2018), other researchers (Bello et al. 2016; Stern et al., 2008; Barab et al. 2009; Birchfield & Megowan-Romanowicz, 2009) have also used an experimental design to determine the impact of technology use throughout science instruction to enhance student comprehension and achievement in science. The researchers all studied the use of simulation techniques to instruct an experimental group. Bello and colleagues (2016) and Stern and colleagues (2008) paired the simulations with instruction in lecture format, whereas Barab and colleagues (2009) and Birchfield and Megowan-Romanowicz (2009) compared the use of the simulations to other traditional instruction styles including lecture and the use of an expository text. Yildirim and Sensoy (2018) used simulation techniques as one of the forms of

technology in their study, however, it was not the only form of technology used to enhance

science literacy. Simulation techniques is a method that allows students to experience the topic

first hand which in turn students create meaning. Some techniques that are used are games,

role-playing, and an activity that acts as a metaphor.   The control group in the research (Bello et

al., 2016; Stern et al., 2008) received instruction through a lecture format. Both studies (Bello et

al., 2016; Stern et al., 2008) found the experimental group yielded significantly higher on

achievement post-test scores than the pre-test scores in the beginning, unlike the control group

who had no use of technology.

       Many researchers (Bello et al., 2016; Stern et al., 2008; Barab et al., 2009; Birchfield &

Megowan-Romanowicz, 2009; Chen & Howard, 2010) also found simulation techniques to be

effective in terms of student engagement and positive learning attitudes. The researchers can

conclude that implementing simulation techniques in science lessons can effectively impact

student academic achievement scores in science. Stern and colleagues (2008) also stated that the

computerized simulation techniques alone would not be enough to increase student

comprehension of the science content, but when paired with a lecture of the material students

gain a better understanding of the content being taught in a science classroom.

       Similar to other researchers (Bello et al., 2016 ; Stern et al., 2008; Barab et al., 2009;

Birchfield & Megowan-Romanowicz, 2009; Chen & Howard, 2010) Chao and colleagues (2015)

and Chang and colleagues (2008) have also used simulations in a science classroom, specifically

the simulations were used in a lab course. The purpose of this study was to determine the

effectiveness of a virtual lab simulation compared to "high-quality traditional lab instruction"

(Chao et al., 2015; Chang et al., 2008). The researchers (Chao et al., 2015; Chang et al., 2008)

found that the experimental group using the virtual lab gained a better understanding of the

science concepts being tested through a post-test questionnaire.

Another form of technology that has been researched (Chiu & Linn, 2013; Chang et al.,

2014; Trey & Khan, 2008) is dynamic visualizations. Dynamic visualizations (DV) are

computerized models that allow students to view a concept that normally cannot be seen in

real-life (Chiu & Linn, 2013; Chang et al., 2014; Trey & Khan, 2008). The researchers used

experimental design to investigate the use of DV in science classrooms on student

comprehension. Trey and Khan (2008) compared assessment scores of two groups. One group

of students were exposed to DV related to the content being taught. The other group of students

did not have access to DV but still received instruction in the content. Chiu and Linn (2013) and

Chang et al. (2014) also used the Web-Based Inquiry Science (WISE) program to create or adapt

science curriculum that contains DV. The researchers used DV to encourage students to create

meaning of the content and potentially add to their previous knowledge. They used the WISE

program to create or adapt their curriculum because it provided a KI structure that encourages

the use of students previous knowledge, the ability of students to create new meaning, and the

ability to synthesize new ideas (Chang et al., 2014). The researchers found (Chiu & Linn, 2013;

Chang et al., 2014; Trey & Khan, 2008) the use of DV to have a positive correlation on student

understanding of science concepts. Chiu and Linn (2013) also used the end-of-year assessment

to determine if the students who were taught through the DV and a KI structure would retain the

information they learned for an extended period of time. These students were able to retain more

information than the students who were not taught with the DV and a KI structure. (Chiu & Linn,

2013).

The Use of Multimodalities in Science Classroom Instruction to Enhance Student Learning

Several researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016) examined the impact of using multimodal methods within science lessons in both middle school and high school. Several researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016) enriched students' content knowledge and increased their academic achievement in science courses. Although the authors (Sarac & Tarhan, 2017; Nair & Bindu, 2016) used different multimodal texts and methods they all yielded similar results pertaining to the use of multimodal texts to enhance student learning. When using multimodalities the researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016) found there was a positive impact on student academic achievement in science.

Multiple researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016) investigated pairing multimodal texts in similar ways. The studies consisted of experimental and control groups. The control groups were taught using the traditional appropriate methods and models of curriculum. Both studies used multimodal texts to teach the experimental groups. The texts used were similar in that the researchers intentions were to implement paired multimodal texts to enhance students learning and attitudes towards the science content being taught. Sarac and Tarhan's (2017) experimental group was taught using multimedia supported teaching materials such as pictures, experimental activity drawings, computer simulations and animations, videos, and presentations prepared according to the 7e learning model. Nair and Bindu (2016) used direct instruction (lecture) then live events (experiments), self-paced learning (individually through internet learning), and collaboration (solve a problem or create a project) to teach biology content. Each phase incorporated materials such as videos, PDFs, resource CDs, and internet. Using the paired multimodal texts the researchers (Sarac & Tarhan, 2017; Nair &

Bindu, 2016) discovered a significant difference between the post-test scores between the control and the experimental groups in that the experimental groups scored significantly higher.

Teachers Use of Multimodalities to Encourage Students Use of Multimodalities to Improve Their Science Literacy

Researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016) have found that using multimodal texts in the science content areas can positively impact student science academic achievement. Other authors (McDermott & Hand, 2012; Nixon, Smith & Wimmer, 2015; Hand & Choi, 2010; Adadan, 2012) have investigated the impact of the teachers use of multimodalities on the students use of multimodalities and how this correlates to student science literacy. Nixon and colleagues (2015), whose participants were middle school students, yielded different results from the other researchers (McDermott & Hand, 2012; Hand & Choi, 2010; Adadan, 2012) whose participants were in high school level science classes or above. Nixon et al. (2015) results were different in that they did not demonstrate noticeable growth in comprehension. Their explanation for this difference was that middle school students may require longer and more focused exposure to the multimodal representations (MMR) than their study provided. Middle school students need longer and more focused exposure because of the "cognitive workload" it takes to create and make meaning of using MMRs (Nixon et al., 2015). The findings of this study points out that explicit instruction of multimodal resources may not be enough to enhance student learning in the middle school. Instead, using multimodal representation within daily instruction to provide examples and to expose students to this type of strategy may be a better way to teach students about multimodal representations and increase their academic achievement in science.

Some researchers (Mcdermott & Hand, 2012; Hand & Choi, 2010) whose participants were in high school and college found that there was a positive correlation between students embedding at least one mode within their work and their conceptual understanding. The researchers (McDermott & Hand, 2012; Hand & Choi, 2010) analyzed student lab reports based on a framework that encouraged the use of multimodal representations (MMR) to make an argument. MMR were used throughout the laboratory instruction and their notetaking, therefore, the students were exposed to MMR and became familiar with how to use them. The researchers were aiming to encourage both high school and college students to use MMR in their reports to create a quality argument. The purpose of the MMR in a student's report was to better support their argument by providing more conceptual information in their reports. The MMR that the students used needed to enhance their argument and connect ideas within their report. The framework used by the students was intended to encourage their use of MMR to represent their argument. McDermott and Hand (2012) took this a step further and taught the high school students how to use MMRs in their writing by giving the experimental group extra time for instruction of MMR and the importance of "embeddedness" which is "embedding multiple modes of representing science." The researchers looked at an embeddedness score to determine the students' use of multimodal representations in communicating their knowledge of science. McDermott and Hand (2012) concluded, that no matter if they had direct instruction of "embeddedness" or not the high school students made improvements in their ability to explain their argument just by including another mode of representation in their writing. The researchers (McDermott & Hand, 2012; Hand & Choi, 2010) found a positive correlation between the use of MMR in a lab report and the student's ability to create a solid argument at the college and high

school level. Therefore, encouraging student's use of MMR in their science reports can increase student comprehension and literacy in college and high school science courses.

Adadan (2012) much like other researchers (McDermott & Hand, 2012; Nixon et al., 2015; Hand & Choi, 2010), sought to determine the effectiveness of teachers using multimodal representations on student's comprehension in science. Similar to the other researchers (McDermott & Hand, 2012), Adadan (2012) also added multimodal representations to high school science class instruction. The MMR used throughout the instruction were verbal (oral and written) and visual and they used a control group which received only the verbal (oral and/or written) representation.   The students receiving MMR were then allowed to present what meanings they had created using both visual and verbal representations. The point of the MMR group presenting with multiple representations was to show how using the MMR could allow students to improve their ability to make connections and create ideas of the content they had learned (Adadan, 2012).

Much like the other researchers (McDermott & Hand, 2012; Hand & Choi, 2010) Adadan (2012) found students demonstrated a greater understanding of the science concepts, through their presentations, from the group that was allowed to use multiple representations. The researchers followed up with the students three months after the initial presentations and discovered the MMR students retained more of the scientific concepts than the control group. The results, similar to other researchers (McDermott & Hand, 2012) provide evidence that using multiple representations while teaching high school science can improve student comprehension (Adadan, 2012).

Summary

Many researchers (Bello et al., 2016; Yacoubian et al., 2011; Eslinger & Kent, 2018) have studied the use of different multimodal texts, such as simulations, primary literature, and trade books in the science classrooms. The researchers found the use of multimodal texts alongside classroom instruction to increase student's science comprehension and literacy. The literature review discussed the articles which were organized into the following 5 themes primary literature, trade books, technology, use of multimodalities in instruction, and teachers use of multimodalities to encourage student use of multimodalities.

Primary Literature. Many researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) demonstrated that the use of primary literature supports content knowledge and a higher order of thinking in college level science courses. However, the use of primary literature was only proven to increase science literacy when the teacher used a specific method, such as the C.RE.A.T.E method or the LBL method. The studies described (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) were only conducted in college level courses, therefore there needs to be more research conducted that involves using primary literature in high school science courses.

Trade Books. Along with primary literature, trade books have also become an effective multimodal text as stated by multiple authors (Yacoubian et al., 2011; Chen et al., 2017; Fang & Wei, 2010; Fang et al., 2008) and when paired with content instruction or the content textbook, trade books can provide a richer more engaging way to communicate the content. The researchers (Fang & Wei, 2010; Fang et al., 2008) determined that the use of trade books within the science classroom can offer students another way to connect with and create meaning of the

content.

       Technology. Aside from primary literature and trade books, there is also an abundance of

research that supports the use of technology to enhance student achievement in secondary

science courses. Several authors (Saltan & Divarci, 2017; Bello et al., 2016; Yildirim & Sensoy,

2018; Stern et al., 2008; Chao et al., 2015; Chang et al., 2008; Chiu & Linn, 2013; Chang et al.,

2014; Barab et al., 2009; Birchfield, & Megowan-Romanowicz, 2009; Trey & Khan, 2008)

discovered the positive impact of technology on student achievement**.** Most importantly, based

on the results from studies of multiple researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016;

Adadan, 2012; Hand & Choi, 2010) technology or other modes of communication, when linked

with multiple modes, improvement of student achievement, and understanding in science is

found to be the result. There is an abundance of researchers (Saltan & Divarci, 2017; Bello et

al., 2016; Yildirim & Sensoy, 2018; Chao et al., 2015; Chang et al., 2008; Stern et al., 2008;

Chiu & Linn, 2013; Chang et al., 2014; Trey & Khan, 2008; Sarac & Tarhan, 2017; Nair &

Bindu, 2016; Adadan, 2012; Hand & Choi, 2010; Barab et al., 2009; Birchfield, &

Megowan-Romanowicz, 2009) that have discovered the advantage students have in the science

classrooms when teachers embed technology within their instruction. Technology such as

simulations, virtual activities, digital graphics and representations of content, and dynamic

visualizations (DV). Many researchers (Bello et al., 2016; Yildirim & Sensoy, 2018; Chao et al.,

2015; Chang et al., 2008; Stern et al., 2008; Birchfield, & Megowan-Romanowicz, 2009)

discovered the use of simulations alongside classroom instruction created a learning environment

where students were engaged with positive attitudes towards learning science content. Stern and

colleagues (2008) concluded the use of simulations alongside instruction increased student

comprehension in science. In conclusion, simulations would be an effective multimodality to implement into the science classroom to increase student science literacy and comprehension.

Use of Multimodalities in Instruction. The researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016) investigated the impact of pairing multimodal texts in science instruction of students academic achievement. Students in the experimental groups interacted with different forms of technology, visuals, and activites that supported the instruction from the teacher. They discovered a significantly higher level of academic achievement in the experimental groups in which they were exposed to a variety of multimodal texts along with the science instruction.

Teacher Use of MMR to Encourage Student Use of MMR. Many researchers (McDermott & Hand, 2012; Hand & Choi, 2010; Adadan, 2012) discovered the positive impact of teachers using MMR in their instruction on students science literacy. Students who were exposed to MMR throughout science instruction were more likely to use MMR when communicating their knowledge of the science content. When the student's used MMR in their writing or presentations to share their knowledge, they received higher scores then the students who did not use MMR. The authors found (McDermott & Hand, 2012; Hand & Choi, 2010; Adadan, 2012) that the students who used MMR were more likely to understand the content they were communicating because they had the support of a visual.

Chapter 3: Methodology

Introduction

Several researchers have indicated there are many multimodal texts to choose from when creating an environment that enhances science literacy (Nair & Bindu, 2016; Sarac & Tarhan, 2017). Many multimodal texts have been investigated and proven to be effective in enhancing student attitudes, academic achievement, science literacy, and content comprehension. Some of the effective multimodal texts are simulations (Yildirim & Sensoy, 2018; Bello et al., 2016), blogs (Saltan & Divarci, 2017), trade books (Yacoubian et al., 2011; Chen et al., 2017; Fang & Wei, 2010; Fang et al., 2008), and primary literature (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011). This research addressed the question of what effective multimodal texts can be implemented within a secondary science classroom to support content comprehension and promote science literacy and how can these texts be implemented?

The question was answered through research synthesis. All major databases and related sources have been searched to find previous research studies that connected to the topic of effective multimodal text in a secondary science classroom and the most impactful ways to implement them. After data collection was completed, the data was analyzed and sub-themes were discovered within the five main themes. Next, a research synthesis of the data analysis determined significant findings. Results of the research synthesis then became the basis for an extensive professional development project.

Data Collection

The studies for this research synthesis were found through a substantial data collection process, in which major educational databases were searched for peer-reviewed research studies.

The articles were found through the following data collection process. The first database searched was the ERIC database, through EBSCO host, using the following search modes; boolean/phrase, peer-reviewed, the years 2008-2018, English, numerical/qualitative data, reports-evaluative, and reports-research. Several keywords and phrases were searched such as science comprehension, multimodalities, science education and the modes of learning. Multiple relevant studies were found through this search (Bang & Luft, 2013; Yildirim & Sensoy, 2018; Bello et al., 2016; Eslinger & Kent, 2018). Using the ERIC database synonyms, such as science literacy in science education and teacher led instruction, science literacy in science education and student led instruction, multiple modes, and science comprehension were used to enhance the previously conducted research. Academic Onefile was then used to search for peer-reviewed research articles. The first phrase used was "Multimodal text in science classrooms." Very few articles came from this search, however, Zhang's study from 2016 cited articles that were relevant to the topic at hand (Adadan, 2012). The articles that were relevant were then searched through the One Search database to check for full text availability. Through One Search other relevant articles resulted after searching the previous article titles (Chang et al., 2014; Chao et al., 2015; Chiu & Linn, 2013). In the end, there were 33 articles found and used within this research synthesis.

Data Analysis

After the conclusion of the research, the relevant articles were categorized into five themes based on the multimodal text being used within that study and how they were being used. The five themes that were analyzed were the use of Primary Literature (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010), use of trade books (Chen et al.,

2017; Fang & Wei, 2010; Fang et al., 2008), use of technology (Saltan & Divarci, 2017; Bello et al., 2016; Yildirim & Sensoy, 2018; Stern et al., 2008; Chao et al., 2015; Chiu & Linn, 2013; Chang et al., 2014; Barab et al., 2009), use of multimodal texts (Sarac & Tarhan, 2017; Nair & Bindu, 2016), and the impact of teacher use of multimodalities on student use of multimodalities (McDermott & Hand, 2012; Nixon et al., 2015; Hand & Choi, 2010; Adadan, 2012). Two categories emerged from the five themes which were the use of *electronic* multimodalities versus the use of *non-electronic* multimodalities in science classrooms. The following section discusses the two categories

Primary Literature. There were four studies found in which the researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) sought to determine the effects of incorporating primary literature into science education. The primary literature in each of the studies were a *non-electronic* multimodal text. Researchers (Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) in three of the studies used methods to encourage college students to read and analyze *non-electronic* research articles to promote science literacy and a higher order of thinking. All of the researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) found the students to be engaged in a high order of thinking and were more confident in their science literacy after analyzing primary literature, a *non-electronic* multimodal text.

Trade books. Three studies were found in which researchers (Chen et al., 2017; Fang & Wei, 2010; Fang et al., 2008) looked at the the effects of *non-electronic* trade books on student science literacy. The researchers determined the use of trade books enhanced student comprehension of the science content and gave the students a chance to see the content on a

deeper level. Researchers from two of the three studies (Fang & Wei, 2010; Fang et al., 2008) instructed the students in reading strategies to use to increase their readability of the science trade books. The strategies were specific for reading science content. One researcher (Chen et al., 2017) used a reward program to motivate their participants to read *non-electronic* science trade books. The students that participated in the reading programs of all three studies demonstrated an increase in science academic achievement and science literacy.

      Technology. There were twelve studies found where researchers (Saltan & Divarci, 2017; Bello et al., 2016; Yildirim & Sensoy, 2018; Stern et al., 2008; Chao et al., 2015; Chiu & Linn, 2013; Chang et al., 2014; Barab et al., 2009; Birchfield & Megowan-Romanowicz, 2009; Trey & Khan, 2008; Chen & Howard, 2010; Chang et al., 2008) conducted studies to determine the effects of technology, *electronic* sources, on science comprehension and literacy. All of the researchers found that implementing the *electronic* sources into a science classroom has shown an increase in science comprehension and literacy. According to all of the researchers, technology enhanced students ability to not only have a higher order of thinking but also create meaning of science content which is the goal of science literacy. One researcher in particular (Saltan & Divarci, 2017) determined the effects of the use of blog activities in a science classroom. They found an increase in student knowledge of science content, specifically environmental literacy, and an increase in student's positive attitude toward the environment with the use of blogs. Another researcher (Yildirim & Sensoy, 2018) developed a study to look at a variety of technology used throughout the lessons in a science classroom. They specifically used digital cartoons/animations, digital stories, simulations, assessments such as puzzles and concepts maps were completed on the computer. The researchers found the use of these

electronic sources significantly increased the student's academic achievement in science and the student's sustained this increase over the course of six weeks.

There were seven studies found where the researchers (Bello et al. 2016; Stern et al., 2008; Barab et al., 2009; Birchfield & Megowan-Romanowicz, 2009; Chen & Howard, 2010; Chao et al., 2015; Chang et al., 2008) used simulations in their studies, another *electronic* source. The researchers aimed to determine if this specific type of technology would have a positive effect on student's science literacy and comprehension. Researchers (Bello et al., 2016; Stern et al., 2008; Chen & Howard, 2010) from three of the seven studies found that when simulations were paired with a lecture format students had significantly higher post-test scores than instruction with only lecture. Researchers (Birchfield & Megowan-Romanowicz, 2009; Barab et al., 2009) from two of the seven studies replaced instruction with simulation technology, which they found to increase student academic achievement in science.   All five researchers (Bello et al., 2016; Stern et al., 2008; Barab et al., 2009; Birchfield & Megowan-Romanowicz, 2009; Chen & Howard, 2010) found simulations, an *electronic* source, to increase student engagement and encourage positive learning attitudes. Additionally, researchers from two more studies (Chao et al., 2015; Chang et al., 2008) focused on the effects of simulation technology, however, their main focus was on implementing simulations into a lab course instead of the lecture course. The students who used the virtual lab simulations demonstrated a better understanding of the science concepts learned in lab than the students who did not work with the virtual lab simulation. Overall simulations, an *electronic* source, is an effective way to increase science literacy and comprehension.

The last form of technology researched was dynamic visualizations. Three studies (Chiu

& Linn, 2013; Chang et al., 2014; Trey & Khan, 2008) were found in the search for studies

focusing on DV, an *electronic* source. The researchers believed DV would allow students to see

concepts first hand that normally cannot be seen by the naked eye. The researchers found that

the use of DV in science classrooms had a positive correlation with student comprehension. Chiu

and Linn (2013) also found that students were able to retain the information by re-testing them at

the end of the academic school year.

Multimodalities within Instruction to Enhance Learning. There were two studies that

were found in which the researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016) aimed to

determine whether using multimodal methods in science classrooms would positively affect

students science literacy. Both researchers found using multiple modes to communicate the

content had a positive correlation with student academic achievement in science. Sarac and

Tarhan (2017) used both *electronic* (simulations, videos, animations) and *non-electronic* sources

(drawings, pictures, presentation files) to engage students in a science lesson called "Matter's

Change Unit."   Nair and Bindu (2016) conducted their study also using *electronic* sources and

non-electronic sources. Their sources of communication were through a virtual classroom and

an in person classroom. Students received "direct instruction" when in the classroom and then

worked individually or with collaborative groups when working in the virtual classroom.   In

both studies the researchers found a significant increase in academic achievement in the

experimental groups who were given multiple modes of communication (both *electronic* and

non-electronic). The control group in both studies also had an increase in academic

achievement, however, it was not as high as the experimental group.

Teacher Use of Multimodalities to Encourage Student Use of Multimodalities. There were four researchers (McDermott & Hand, 2012; Nixon et al., 2015; Hand & Choi, 2010; Adadan, 2012) who investigated the effect of teachers using multimodalities, both *electronic* and *non-electronic*, within classroom instruction to encourage students to use multimodalities to demonstrate their content comprehension.   Nixon et al. (2015) determined the students demonstrated the need for further exposure to the use of multiple representations to increase their understanding of their meaning and how they should be used in student work. Two researchers (Mcdermott & Hand, 2012; Adadan, 2012) found that with teacher use of multiple representations, students then used at least one mode of representation in their lab reports. The use of at least one mode of representations improved the students quality of argument in their lab report. One researcher (Hand & Choi, 2010) studied teachers use of multimodal representations that are *non-electronic* (graphs, pictures, drawings) and the effect it has on students use of multimodalities. The students were instructed with the use of multimodal representations and were then expected to create lab reports where they embedded multimodal representations. The students embedded *non-electronic* multimodalities such as graphs or drawings. Hand and Choi (2010) found that using multimodal representations within instruction encouraged students to also use them in their reports. When students used the *non-electronic* multimodal representations in their reports they improved their explanations and arguments. The researchers (Hand & Choi, 2010) found the students demonstrated a greater scope of scientific knowledge with the use of the multimodal representations.

Table 1
Summary of Data Analysis: Source Type

Source Type	Primary Literature (4 studies)	Trade Books (3 studies)	Technology (12 studies)	Embedded Multimodalities (2 studies)	Student use of Multimodalities (4 studies)
Non-Electronic	X	X			
Electronic			X		
Non-Electronic and Electronic				X	X

Synthesis

An evaluation of the data analysis will occur to synthesize findings that will address the research question: What are effective multimodal texts that support content comprehension and science literacy and how can these resources be implemented in the secondary science classroom? The most significant finding thus far is that the use of multimodal texts (technology, trade books) in a secondary science classroom will have a positive impact on student learning. Table 2 demonstrates which multimodalities should be implemented at the varying grade levels and why they work well at that level.

Table 2

Data Analysis: Multimodalities at Varying Levels of Education

	College (Undergraduate)	High School (9-12)	Middle School(5-8)
Primary Literature (Non-Electronic) (4 Studies)	- Increase science literacy and higher order of thinking (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) - Challenges student to engage in scientific research (Parent et al., 2010) - Allows student to make connections between lab activities and actual research (Hoskins et al., 2011)		
Trade Books Non-Electronic (3 Studies)		- Increase science literacy through deeper exposure of content - Students need to be motivated to get involved in reading programs - Typically students are rewarded for reading in these programs. (Chen et al., 2017)	- Increase science literacy through deeper exposure of content - Students are taught reading strategies to use while reading scientific literature (Fang & Wei, 2010; Fang et al., 2008)

	College (Undergraduate)	High School (9-12)	Middle School(5-8)
Technology Electronic (12 Studies)	- Increase science literacy - Students were more motivated and engaged (Barab et al., 2009)	- Increase science literacy - Students were more motivated and engaged (Chao et al., 2015; Chang et al., 2008; Chiu & Linn, 2013; Chang et al., 2014; Trey & Khan, 2008; Birchfield & Megowan-Romanowicz, 2009)	- Increase science literacy (Saltan & Divarci, 2017; Bello et al., 2016; Stern et al., 2008; Chen & Howard, 2010; Yildirim & Sensoy, 2018). -Increased student attitude towards science (Saltan & Divarci, 2017) - Students were more motivated and engaged(Saltan & Divarci, 2017; Bello et al., 2016; Stern et al., 2008; Chen & Howard, 2010)
Embedded Non-Electronic Electronic (2 Studies)		- Increase science literacy (Sarac & Tarhan, 2017)	- Increase science literacy (Nair & Bindu, 2016)
Influence Non-Electronic Electronic (4 Studies)	- Increase science literacy. - Improved arguments with better explanations (Hand & Choi, 2010)	- Increase science literacy - Improved arguments with better explanations (Mcdermott & Hand, 2012; Adadan, 2012)	-Students did not improve - Researchers believe they needed more exposure to multimodal representations (Nixon et al., 2015)

Primary Literature. There were four studies in which researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) examined the use of primary literature as a source of content communication to enhance science literacy at the

collegiate level. As Eslinger & Kent (2018) highlighted in their research, the majority of the

college students in their study were unable to identify primary literature. Therefore, *college*

students will benefit from increased exposure to primary literature. All of the researchers

(Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) reported

college students having increased confidence in understanding scientific research from exposure

to the primary literature and an increase in critical thinking skills. In two of the four studies,

researchers (Hoskins et al., 2011; Parent et al., 2010) found the *college* students demonstrated

their comprehension of how scientific research is carried out in real life. According to the

researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al.,

2010), primary literature requires a higher order of thinking that needs to be supported with

instruction and has mainly been used in science classrooms that are at *collegiate* levels.

  Trade Books. There were multiple researchers (Chen et al., 2017; Fang & Wei, 2010;

Fang et al., 2008) who studied the effects of trade books on student science literacy at the *middle*

and high school levels. They all determined the use of trade books enhanced student

comprehension at the *middle and high school* levels in science. They found the trade books gave

a more developed view of the content which encouraged students to create meaning and have a

better understanding in science. In two of the studies, researchers (Fang & Wei, 2010; Fang et

al., 2008) used participants in the *sixth* grade to incorporate reading strategies into the science

classroom and a "Home Science Reading Program" (HSRP). The *sixth grade* students, who

participated in reading lessons and the HSRP, demonstrated greater science comprehension than

the control group who did not use trade books or have reading strategy instruction. In another

study, the researchers (Chen et al., 2017) used participants in *high school* to determine the effects

of trade books on student's science comprehension. They found *high school* students who

participated in the reading program had increased science comprehension and literacy based on

academic achievement scores. According to the research trade books has been beneficial at both

the *middle and high school* levels with the use of reading strategy instruction for the *middle*

school levels (Fang & Wei, 2010; Fang et al., 2008).

      Technology. The use of technology has been studied throughout all three academic levels

(college, high school, middle school) by many researchers (Saltan & Divarci, 2017; Bello et al.,

2016; Yildirim & Sensoy, 2018; Stern et al., 2008; Chao et al., 2015; Chiu & Linn, 2013; Chang

et al., 2014; Barab et al., 2009; Birchfield & Megowan-Romanowicz, 2009; Trey & Khan, 2008;

Chen & Howard, 2010; Chang et al., 2008). All the researchers conducted studies to determine

the effects of various forms of technology on student science literacy. In one study the

researchers (Saltan & Divarci, 2017) determined the effects of the use of blog activities in a

seventh grade science classroom. They found the *seventh* grade students to have increased

positive attitudes towards the environment and environmental literacy. Another form of

technology that was researched was Dynamic Visualization (DV). The researchers (Chiu &

Linn, 2013; Chang et al., 2014; Trey & Khan, 2008) found that the use of DV in *high school*

science classrooms had a positive correlation with student comprehension. Other researchers

(Yildirim & Sensoy, 2018) developed a study to look at a variety of technology used throughout

the lessons in a *seventh* grade science classroom. They found the *seventh* grade students who

were exposed to technology had significantly higher academic achievement scores in science.

The researchers then concluded the *seventh* grade students to have had an increase in science

comprehension.

Yildirim and Sensoy (2018) used simulations as one of their forms of technology to enhance *seventh* grade student's science literacy and engagement. In three studies, other researchers (Bello et al., 2016; Stern et al., 2008; Chen & Howard, 2010) used simulations in *middle school* (grades 7-9) science classrooms to enhance science literacy. They found that when simulations were paired with a lecture format students had significantly higher post-test scores than instruction with only lecture. Stern and colleagues (2008) indicated that simulation technology alone was not enough to increase academic achievement in a *seventh* grade science classroom, but when paired with a lecture the scores on post-assessments increased. In another study, researchers (Birchfield & Megowan-Romanowicz, 2009) used simulations, however they studied simulations within a *high school* Earth Science classroom. They replaced instruction with simulation technology, which they found to increase student academic achievement in science. Barab et al. (2009) also replaced instruction with simulation techniques, but they focused at the *collegiate* level. They also found student academic achievement increased with exposure to simulation technology. Additionally, researchers (Chao et al., 2015; Chang et al., 2008) of two more studies focused on the effects of simulation technology, however, they implemented simulations into a *high school* lab course and found similar results, in that student engagement and achievement increased.   All seven researchers (Bello et al., 2016; Stern et al., 2008; Chen & Howard, 2010; Chao et al., 2015; Chang et al., 2008; Birchfield & Megowan-Romanowicz, 2009; Barab et al., 2009) found increased student engagement, attitude and achievement in all three academic levels (*middle school, high school, college*).

Multimodalities within Instruction to Enhance Learning. There were two studies in which the researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016) found using multimodal

methods at the *middle and high school* level science classes increased students science literacy. Both teams of researchers found using multiple modes to communicate the content had a positive correlation with student academic achievement in science. Sarac and Tarhan (2017) conducted a study using participants in the *fifth* grade. They found the fifth grade students increased their academic scores with the assistance of the multimodalities, however, the multimodalities used were based off of the "7e learning model."   Nair and Bindu (2016) conducted their study using participants in *high school* science courses and also found the use of various multimodalities to be beneficial to student academic achievement.

Teacher Use of Multimodalities to Encourage Student Use of Multimodalities. In one study, the researchers (Nixon et al., 2015) found that *middle school* students may need more exposure to and explicit instruction of the Multimodal Representations (MMR) to increase their comprehension. The researchers noted the "cognitive workload" required to understand MMR may be far greater than a middle schooler can process. The short time frame of the study was not enough to increase student comprehension in *middle school* science. In another two studies, researchers (Mcdermott & Hand, 2012; Adadan, 2012) focused their research at the *high school* level and found the students were equipped to understand MMR and found the students were using MMR in their lab reports after exposure to teacher use of MMR. The use of MMR in their lab reports improved their arguments and explanations. Another researcher (Hand & Choi, 2010) also found with teacher use of MMR within instruction the students were more likely to use MMR within their reports. Their research, however, was conducted using participants at the *collegiate* level.

Several researchers (Chao et al., 2015; Chang et al., 2008; Birchfield &

Megowan-Romanowicz, 2009) found, when implementing simulations into science courses at the *high school* level, student's science literacy was enhanced. They also found simulations created a positive, motivating, and science literacy learning environment. Therefore, simulations are an effective multimodal text to be implemented into high school science classrooms to enhance science literacy and comprehension.

Chapter 4: Results and Applications

Results of the Review

The research question proposed was: What are effective multimodal texts that support content comprehension and science literacy and how can these resources be implemented in the secondary science classroom? This research question was formulated to analyze studies where researchers addressed a variety of multimodalities implemented into science classrooms at the high school level. The first finding produced from this data synthesis was that trade books and technology were mostly used and very effective in high school and middle school level science courses. The second finding was that primary literature was an effective multimodal text for students at the collegiate level. The third finding produced was embedding multimodalities within instruction at the middle school and high school levels was beneficial to a students science literacy.   The fourth finding was that the use of simulations in a science course enhanced student learning, comprehension and science literacy at the high school level.

Looking at the first finding there were multiple researchers (Chao et al., 2015; Chang et al., 2008; Chiu & Linn, 2013; Chang et al., 2014; Trey & Khan, 2008; Birchfield & Megowan-Romanowicz, 2009; Saltan & Divarci, 2017; Bello et al., 2016; Stern et al., 2008; Chen & Howard, 2010; Yildirim & Sensoy, 2018) who found that the use of technology in science classrooms at the middle and high school levels demonstrated increased student comprehension and science literacy. Many researchers (Chen et al., 2017; Fang & Wei, 2010; Fang et al., 2008) found that trade books used at the middle and high school level science classrooms also demonstrated an increase in their science comprehension through seeing the content at a deeper level. The second finding was based off researchers (Eslinger & Kent, 2018;

Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) who discovered students science comprehension and literacy skills were increased with the use of primary literature as part of instruction in college level courses. Their results indicated students having a higher order of thinking after being exposed to the primary literature. According to researchers (Sarac & Tarhan, 2017; Nair & Bindu, 2016), in support of the third finding, when embedding multimodal representations into science instruction at the middle school and high school levels, students comprehension and literacy increased. The fourth finding involved many researches (Birchfield & Megowan-Romanowicz, 2009; Chao et al., 2015; Chang et al., 2008) who found, implementing simulations in high school science instruction, the students comprehension and literacy increased. According to the researchers students are exposed to more life like scenarios and can see the content in reality versus just on paper. The researchers found students were not only improving in science comprehension, but they also became more engaged in the content when using simulations as a multimodal text.

Application of the Results to a Professional Development Project

The main finding of this data analysis was that implementing simulations in high school science classrooms has demonstrated a positive impact on student comprehension, literacy, and engagement. High school science educators should be informed of this finding and would benefit from having a better understanding of the effectiveness of simulations. Simulations are a highly researched multimodal text and has had a significant impact on student science literacy and comprehension (Yildirim & Sensoy, 2018; Bello et al., 2016; Stern et al., 2008; Chen & Howard, 2010; Birchfield & Megowan-Romanowicz, 2009; Chao et al., 2015; Chang et al., 2008; Barab et al., 2009). Therefore, a professional development project was created based on

this new knowledge. High school science educators, in all science areas (*biology, chemistry, physics, earth science*) were given access to the professional development through a website link that was distributed through an email informing the educators about the professional development being provided.

Design of the Professional Development Project

The professional development project consisted of an informative resource in which teachers could access at any time. The professional development project was created through Google Sites and contained many resources encouraging high school science educators to implement the use of simulations. The Google Site was available for high school educators in all science areas, biology, chemistry, physics, and earth science. There was no cost to access the Google Site. The simulation resources provided contain simulations pertaining to each content area and therefore addressed simulations in all science areas at the high school level. The Google site consisted of seven informative pages (See Appendix A). The first page contained the pre-assessment to determine science teacher's previous knowledge of simulations. The second page contained researched tips and tricks on how to implement simulations into a science classroom, such as using simulations within lab versus lecture class. The third page contained links to research articles that were analyzed for this study. Each research article was summarized with the grade level, subject, and how the simulations were implemented. The fourth page contained links to credible simulation programs that can be implemented in any high school science course. The fifth page contained potential lesson plans individualized for each science content area that aligned with the Next Generation Science Standards. The sixth page contained the post assessment to demonstrate what the science teachers learned from the professional

development site. High school science teachers who completed the professional development submitted a summary of what they learned from the Google Sites, how they implemented simulations into their science classroom, and what their results were based on student quizzes or lab scores. Along with the quiz and lab scores, the teachers submitted a discussion paragraph explaining if their students demonstrated science literacy and comprehension after exposure to simulations in their science classroom. The summary was submitted through a Google Form which is on the last page of the Google Site. The high school science teachers were asked to upload a video of a discussion with their students as a whole group to the Google Site (also on the last page). The topic of the whole group discussion was how the students felt about simulations being added to their classroom, if they were engaged while using them, and if they felt the simulations increased their comprehension of the content.

The Google Site was distributed to different districts both rural and urban. The high school principals and literacy specialists were contacted and those who were interested met and discussed the benefits of using simulations in a high school science classroom. The high school principals and literacy specialist then watched the YouTube video that demonstrated how to use the Google Sites. The YouTube video contained an overview of the Google Site, how to navigate through the Google Site, and how to give feedback on their thoughts pertaining to the Google Site. They then were able to view and experience the Google Site. Those who decided to move forward with the professional development were given access to the Site and video in which they distributed to their high school science educators through the school's email network.

Literacy Coaching Project Goals and Objectives. The goal of this professional development was to inform high school science educators, of all science content areas (biology,

earth science, chemistry, and physics), of the use of simulations to effectively enhance student literacy in high school science classrooms. In order to meet this goal a few strategies were used such as the Google Site facilitated collaboration between high school science educators, administrators and literacy specialists, it was was self-paced, and in the end the teachers were evaluated on the knowledge they gained. At the end of the professional development high school science teachers were able to see the results of using simulations within their classroom through student interviews, quiz grades, and lab reports.

Proposed Audience. The audience that this professional development has been created for are science teachers at the high school level in any science course (biology, earth science, chemistry, or physics). The literacy specialists are advocates for simulations in the science classroom, since they enhance literacy in science. Therefore, literacy specialists were initially contacted, along with the high school principals, with the link to the Google Site. After presentation of the professional development, the literacy specialists and high school principals then distributed the link and YouTube video to the science educators. The Google site was easily searched through terms related to "simulations in science." Anyone with the link could access the Google Site, without a password or google account.

Proposed Project Format and Activities. The professional development was an informative resource created through Google Sites. For ease of access, there was a link distributed to the literacy specialists, high school principals, and science educators. The Google Site began with a pre-assessment to determine the previous knowledge of each science teacher (See Appendix A). The results of this pre-assessment determined which page the teacher started on. For instance if a science teacher demonstrated proficiency in simulations and agreed that

simulations were an effective tool to use in their classroom, they started on page 3 where there

were links to content specific simulations. On the Google Site there were five pages (See

Appendix A) that informed educators about why simulations were effective in science

classrooms and how they enhanced science literacy through synthesis of research data. The site

also contained examples of the different types of simulations and lesson plans to choose from.

There were links to free simulations and information about simulations that may require a

purchase. To provide an enhanced learning environment throughout the professional

development, there were multiple activities to encourage science educators to interact with the

simulations. For each science content area there was a simulation link paired with a WebQuest

link that requests the educators to complete a task after viewing the simulation. This task

required educators to collaborate with at least one other science educator through comments on

the Google Site. They were instructed to discuss how the particular simulation would fit into

their classroom, how long the lesson might take, and how would they evaluate the students

learned knowledge. After implementing the simulation into their classrooms, science educators

were directed to use the Duo application to video conference with the same educator to discuss

their thoughts and feedback on how the lesson went. Another activity that the educators were

required to complete was to find another simulation to contribute to the Google Site. There was

a section for commenting on the simulation resources page where teachers posted the links to the

simulations they found. The high school science teachers then completed the post assessment to

determine the knowledge they gained from this professional development. The last activity was

to provide constructive feedback on the lesson plans provided and the simulation links that were

provided.

Proposed Resources for Project. The professional development project required access to google sites through an electronic device and internet access. Google sites was free, easily accessed, and did not require you to have a google account. As long as you could access the link you could use the Google Site. The Google Site could be accessed from a mobile device, computer, or tablet. The last resource the educators and literacy specialists needed was the Duo application. This was downloaded to any device with a camera. The Duo application allowed the teachers, from any device (iPhone, Android, Tablet, iPad, computer), to connect via video conference. Duo was used when the science educators were asked to collaborate with other science educators to discuss how one particular simulation could be implemented into their classrooms.

Proposed Evaluation of Project. Science educators (biology, earth science, chemistry, physics), literacy specialists, and high school principals had the opportunity to evaluate the professional development (See Appendix B). Professional development evaluation participants responded yes or no to ten statements that reflected on their experience of completing the professional development dealing with simulations in high school science classrooms. Participants addressed the accessibility of the Google Site, the organization of the Google Site, the accuracy of the Google Site, and the usefulness of the Google Site. The purpose of the evaluation was to provide feedback to the presenter to support further development of the simulation topic.

Project Ties to Professional Standards. This professional development project aligns with several of the International Reading Association (IRA) *Standards for Reading Professionals* (2010). This Google Site will aim to encourage educators to further their teaching knowledge

which aligns with standard 6 which proposes "Candidates recognize the importance of, demonstrate, and facilitate professional learning and leadership as a career-long effort and responsibility." Another standard that aligns with this professional development is standard 5 proposes "Candidates create a literate environment that fosters reading and writing by integrating foundational knowledge, instructional practices, approaches and methods, curriculum materials, and the appropriate use of assessments." Educators are required to provide a literacy based environment with multiple modes of communication. Simulations are an effective mode to communicate science content. This professional development project also aligns with standard 2 which proposes "Candidates use instructional approaches, materials, and an integrated, comprehensive, balanced curriculum to support student learning in reading and writing." The professional development project also aligns with the Common Core State Standards (2010). The standard aligned with this professional development is Grades 11-12 literacy in science, CCSS.ELA-LITERACY.RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. This standard describes the exact goal of this professional development which is to provide science educators with a multimodal text that will enhance science literacy and encourage students to create meaning of the science content.

Chapter 5: Discussion and Conclusion

Overview of Study and Findings

Many different multimodal texts have been found by researchers (Nair & Bindu, 2016; Sarac & Tarhan, 2017) to be an effective way to communicate science content and is becoming more widely accepted in classrooms (Jacobs, 2012). The use of these multimodal texts when used properly are an effective way to enhance student learning (Varma et al., 2008; Bang & Luft, 2013). A problem stated by Bang and Luft (2013), is that teachers who use the multimodal texts (specifically electronic) do not fully understand how they should be used to enhance student learning. In their study, teachers are using the technology just as a way to display what the teacher is lecturing. Bang an Luft (2013) are suggesting teachers should be implementing blogs, simulations, virtual teams, and role playing which are more interactive technology sources as opposed to a powerpoint to display the content. This lack of a multimodal environment leads to the question: What are effective multimodal texts that support content comprehension and science literacy and how can these resources be implemented in the secondary science classroom? The question was then answered through an extensive research process, literature review, data analysis and research synthesis. The research synthesis resulted in the following findings; the first is the use of technology and trade books in science classrooms at the middle and high school levels demonstrated increased student comprehension and science literacy. the second is students science comprehension and literacy skills were increased with the use of primary literature as part of instruction in college level courses, the third is when embedding multimodal representations into science instruction at the middle school and high school levels student comprehension and literacy increased, the fourth is after implementing simulations in

high school science instruction, student comprehension and literacy increased.

The professional development that was created to address the research question was a Google Site that presents educators with information about simulations (an effective multimodal text) and why they are effective in a high school science classroom. The Google Site also addresses the portion of the question that asks how will the multimodal text be implemented into the science classroom. The professional development contains activities for educators to interact with the simulations and lesson plans that incorporate the simulations to effectively enhance student science literacy.

Significance of the Findings

These findings were significant to the science education field and added to the well established bank of knowledge that supports the use of various multimodal texts in science classrooms. The first finding was based off of many researchers (Saltan & Divarci, 2017; Bello et al., 2016; Yildirim & Sensoy, 2018; Stern et al., 2008; Chao et al., 2015; Chiu & Linn, 2013; Chang et al., 2014; Birchfield & Megowan-Romanowicz, 2009; Trey & Khan, 2008; Chen & Howard, 2010; Chang et al., 2008) who used technology to enhance science literacy and were using participants at the middle school and high school levels. All of these researchers found the use of technology to enhance student comprehension in the science classroom. This research was significant for high school and middle school science teachers in support of technology being used in their classrooms. The second finding was significant at the collegiate level. Researchers (Eslinger & Kent, 2018; Carter & Wiles, 2017; Hoskins et al., 2011; Parent et al., 2010) found the use of primary literature to be an effective way to communicate content and engage students in real life scenarios. They found this enhanced student comprehension at the

collegiate level. The significance of the third finding was that middle and high school science educators were supported by authors (Sarac & Tarhan, 2017; Nair & Bindu, 2016) who found that embedding multimodal representations within their instruction increased student comprehension and literacy. The fourth finding was significant for high school science educators in support of using simulations within their classrooms. Multiple researchers (Birchfield & Megowan-Romanowicz, 2009; Chao et al., 2015; Chang et al., 2008) after implementing simulations into a high school science classroom students were more engaged with the material and demonstrated an increase in science comprehension and literacy. The findings from this research synthesis were significant to both the science education field and the literacy field in that the use of the multimodal texts was shown to increase science literacy at multiple grade levels. The research that was synthesized provided a current overview of the different types of multimodal texts that were demonstrated to be effective and at what grade level was appropriate for each multimodal text.

Limitation of the Findings

There were a few limitations that were considered when writing this research study. The first limitation was the time that was allotted to complete the research study. This study was completed over the course of two semester, if given more time, more research could be reviewed and used to support the findings. The second limitation was the use of only three databases to find research in support of multimodal texts in the science classroom. The use of more databases could have yielded more articles to support the findings. The third limitation was that the research was based on the upper grade levels (middle school, high school and college), no research was viewed in support of multimodal texts within the elementary grade levels. The

fourth limitation was many of the studies were outdated and could not be used in this research study.

Conclusion: Answer to the Research Question

The research question in this study was: What are effective multimodal texts that support content comprehension and science literacy and how can these resources be implemented in the secondary science classroom? The answer to this proposed question came from the findings in which technology was found to be an effective multimodal texts for middle school and high school, primary literature was found to be an effective multimodal text for college students, embedding multimodal representations into instruction was found to be effective for both high school and middle school, and simulations were found to be an effective multimodal text for high school students in science classrooms. The professional development provided the answer to how simulations have been implemented into a high school science classroom effectively to enhance student science literacy. The findings presented provided a supportive answer to the research question. Secondary (high school 9-12) science teachers have used simulations, an electronic multimodal text, to provide an appropriate mode to communicate science content and to create learning environment that enhances science literacy.

Recommendations for Future Research

The first recommendation is to continue the research of simulations used in high school science classrooms. However, it is suggested that researchers should create studies that expand over longer periods of time to determine if increased student knowledge of simulations will further enhance student comprehension of science content. The second recommendation is to expand the research of using simulations into science laboratory classrooms at the high school

level. There were few studies found where researchers used participants in laboratory

classrooms and none were found at the high school levels. The third recommendation is to

create an empirical research study in which researchers use more than one simulation activity

within a lesson to determine if student science literacy and comprehension will increase with

multiple exposures to various simulations related to the same content.

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Appendix A: Outline of Professional Development

Page 1- Pre-assessment

       -What do you already know about simulations?

       - Where will you start within this professional development site?

Page 2- Researched tips and tricks on how to implement simulations into a science classroom

Page 3- Research articles in support of simulation use in high school science classrooms

Page 4- Credible simulation programs for high school science classrooms

Page 5- Lesson plans that contain simulation activities

       - Aligned with Next Generation Science Standards

       - Specific content area lesson plans

       - Feedback section

              -What lesson did you use?

              - Did you like it?

              - Would you use it again? Change it? Share it?

Page 6- Post-assessment

       -What have you learned?

Page 7- Google Form- Submission of summary

       What did you learn?

       How did you implement simulations?

       What were your student's results (lab and or quiz scores) and why?

       Upload video of class discussion

Appendix B: Evaluation of Professional Development

Evaluation Through Google Forms of Professional Development: Simulations in Science

In your opinion...

1. Did the professional development meet the objectives described by the presenter? How?

2. Was the professional development well organized and easy to follow? Would you change anything?

3. Was the professional development easily accessible at your convenience? How could it be more convenient?

4. Was the professional development suitable for the audience intended? Who else should be included in the audience?

5. Was the professional development well researched and was there enough support for simulations being an effective multimodal text?

6. After completion of the professional development go back to the Google Site, are you still able to access it?

7. a. How did you implement simulations? Please describe the lesson you taught.

   b. Did you feel confident when implementing the simulation into your science classroom? Would you share what you did/learned with other high school science teachers?

8. How did your students react to the use of simulations embedded in your lesson plans?

9. What would you like to see changed within this professional development site?

10. Will you continue to use simulations in your classroom? Which ones or did you choose to find your own?