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Developing a Theoretical Framework for Visualization-Based Pedagogical Content Knowledge (V-PCK) Based on Middle School Teachers' Views and Uses of Visualizations as an Instructional Tool

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DEVELOPING A THEORETICAL FRAMEWORK FOR VISUALIZATION-BASED PEDAGOGICAL CONTENT KNOWLEDGE (V-PCK) BASED ON MIDDLE SCHOOL TEACHERS' VIEWS AND USES OF VISUALIZATIONS AS AN INSTRUCTIONAL TOOL

by

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ABSTRACT

Visualizations is a categorical term that is often used to provide visual imagery to the communication of processes, concepts, exemplar phenomena, and general information. Objects such as graphs, tables, diagrams, animations, and pictures fall in this category. Existing literature focuses primarily on the use of visualizations in the science field at the high school level, collegiate levels, and in pre-service teacher education programs. A gap in the literature exists which examines how science teachers at the middle school level perceive and use visualizations as instructional components in the classroom. The purpose of this study was to examine science teachers views on the barriers and facilitators that guided visualization-based instruction in middle school science classrooms. Participants in this study included three science teachers from a small urban middle school in the Southern region of the United States. Grounded theory was used to collect data through semi-structured interviews, classroom observations, lesson plan analysis, card sorting tasks, and a learning style inventory. Data was deductively coded to determine trends which resulted in the development of the theory, Visualization-based Pedagogical Content Knowledge (V-PCK). Results also indicated that while teachers viewed visualizations in a positive manner, their use of visualizations were limited to methods that produced little to no new student knowledge. Integration into the classroom was heavily influenced by the classroom environment and teachers' previous experiences with visualizations. The findings of this study indicated there is a need for professional development opportunities in this area to better allow teachers to utilize visualizations as a teaching and learning tool in the middle school science classroom.

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DEDICATION

This dissertation is dedicated to my sister, Elisha Samuel Watson.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

2-D	Two-dimensional
3-D	Three-dimensional
B.C.	Before Christ
CLT	Cognitive Learning Theory
DOK	Depth of Knowledge
ELL	English Language Learner
IRB	Institutional Review Board
K-12	Kindergarten through Grade 12
PCK	Pedagogical Content Knowledge
U.S.	United States
V-PCK	Visualization-based Pedagogical Content Knowledge

CHAPTER I - INTRODUCTION

1.1 Statement of the Problem.

Many factors have been identified as playing a role in how teachers designed instruction for their middle school science students. Teachers may be aware of a variety of instructional practices that support student learning; however, a number of factors influence whether or not those practices are implemented in the classroom. These factors include teachers' beliefs toward how students learn (Wong, 2016), the type of pre-service or alternative route teacher program used (Arce, Bodner, & Hutchinson, 2014), and their comfort level with the content (Saka, Bayram, & Kabapinar, 2016). Additional factors such as their ability to manage classroom behaviors (Zuckerman, 2007), their stress levels, the amount of time devoted to preparing daily lessons (DiBiase & McDonald, 2015), and even their level of satisfaction with their job (Song & Mustafa, 2015) have been found to have major implications.

There is a wide range of methods used to convey science instruction in classrooms. This varies from project-based learning, inquiry-based activities, blended learning, rote activities, lecture, and student projects. Teachers may also integrate strategies to support students who are English Language Learners (ELLs), receive services from the Special Education Department, whose reading abilities are above or below grade level, and who struggle with specific concepts. Other strategies are incorporated to support student needs on an individual or class-by-class basis.

Effective science teachers have the ability to represent important ideas and abstract concepts in ways that make them understandable to others (Munck, 2007). Teachers' effectiveness in delivering science instruction is directly related to how well students gain a conceptual understanding of science (McNally, 2016; Munck, 2007; Shechtman, Roschelle, Haertel, & Knudsen, 2010). As teachers mature in their profession, they can configure their instructional strategies to support the diverse needs of students within a given classroom with a higher level of proficiency. One tool that can help students develop a deeper understanding of science and science processes is visualizations.

Visualizations have been used as a categorical term for objects such as tables, diagrams, graphs, animations, and simulations. The category also includes mental models which are internal images formed by the brain as it receives and processes external information (Gilbert, 2005). Because science instruction often begins with the explanation and understanding of exemplar phenomena, the use of models play a critical role in helping students develop understanding. The development and use of models and visualizations enhances students' understanding of the content and aids them in identifying relationships, causes, and science phenomena (Chang, 2013). Because of this, the strategic integration of visualizations into instruction assists students in understanding and processing scientific information (Bilbokaitė, 2009).

The middle school years have been identified as a period when students' interest in the sciences decreases or is questioned (Organisation for Economic Co-Operation and Development, 2008). In elementary school, students have an interest in science, as well as their other subjects. It is believed that during the middle school years, students begin to make determinations about their ability to perform well in science. Students' opinions of science, their teachers, professionals in the field, and ultimately, their decision to continue studying science are all influenced by their attitudes regarding science (Ali, Yager, Hacieminoglu, & Caliskan, 2013; Skin, Adedokun, Wackerly, Parker, Mennonno, Miguel, 2015). By the time students reach high school, they may have already determined whether they are good in science and whether they are interested in it. Therefore, during the middle years, students' attitudes solidify regarding their interest and their ability to perform well in science.

Depth of teachers' content knowledge, teaching styles, student activities, and the integration of instructional supports are crucial components that influence student learning. Within the course of the day, teachers must internalize an extensive body of pedagogical knowledge and skills to use in different contexts (McConnell, Parker, & Eberhardt, 2013). In addition, the manner in which content is communicated to students conveys what is essential about a subject (Shulman, 1987). Therefore, teachers play an important role in how a concept is introduced to students, which, in turn, has an effect on student performance and interest in that area.

Visualizations have been reported as being one of the most important cognitive aids enabling students to process scientific information at all levels of education (elementary, secondary, and post-secondary) (Rundgren & Tibell, 2010). School districts across the country are looking for ways to increase rigor and student success in the classroom. At the middle school level, the role visualizations could play in helping school districts meet this goal has not been thoroughly explored. Much of the data available on visualizations focus on its use at the collegiate level (Rybarczyk, 2011; Terrell & Listenberger, 2017). There is also extensive research that highlights high school use in specific courses such as chemistry, biology, and physics (Homer & Plass, 2009; Stieff, 2010).

Education researchers have made attempts to streamline the implementation of visualization tools for students because of the important role they place in perceiving, understanding, and communicating data (Daily, James, Roy, & Darnell, 2015; Stieff, Bateman, & Uttal, 2005). Advocates for the use of visualizations can be found among teachers at all levels. High-school teachers have reported that visualizations were essential in helping students understand scientific concepts, and they played a role in keeping students engaged in class (Cook, 2011). College teachers have reported similar benefits including attributing visualization tools with enriching traditional pedagogies (Stieff et al., 2005). In addition, K-12 and college science textbooks have played a role in accurately representing scientific phenomena (Khine & Liu, 2017; Wiley, Sarmento, David, & Thomas, 2017). A minimal percentage of visualization research that has been published has focused on the middle school level. Most of the middle school research that exist looks at the effect of visualizations on student learning. A gap in the literature exists that focuses on visualization use by middle school teachers, including their perspectives, experiences, and factors that determine their use in the classroom. Visualization use by middle school teachers is important to consider since the teacher is the driving force in the classroom. The teacher's decision to utilize a specific teaching tool, such as visualizations, can have a direct impact on student interest and performance in science courses.

The purpose of this study is to identify the barriers and facilitators of the use of visualization-based instruction among middle school science teachers. Further, this study seeks to describe through multiple data sources the frequency in which these techniques are used. This study is designed to focus on understanding middle school teachers' experiences with visualizations at a small, southern, middle school such that their experiences can be theorized.

1.2 Research Questions.

The research question for this study is:

What are the barriers and facilitators that guide visualization-based instruction by middle school teachers in science classrooms?

Subquestions for this study are:

1. How do middle school science teachers view visualizations as an instructional tool compared to other instructional tools?
2. How are middle school science teachers planning for and using visualizations in the classroom?
3. What types of training have middle school science teachers obtained in the use of visualizations as an instructional tool?
4. What factors influence the use of visualizations in the middle school science classroom?

1.3 Definition of Terms.

Animation: dynamic representations of processes or systems usually used to illustrate events or concepts (Rundgren & Tibell, 2010)

Blended learning: instructional approach for students that is a blend of online platforms and face-to-face classroom methods in which the student experiences individualized pace, a specific structure of learning, and have a greater control over the learning process than traditional classroom methods alone

Card sorting task: a task in which participants are asked to sort cards detailing descriptions or scenarios according to specific guidelines; participants are often asked to verbalize their thought process

Coding: a process of tagging snippets of the data according the major themes that are associated with a piece of evidence

Cognitive load: multidimensional construct representing the load that performing a particular task imposes on a learner's cognitive system (Takir & Aksu, 2012)

Concept map: a two-dimensional graphic or schematic diagram that assists in organizing thoughts, concepts, and recognizing patterns (Lott & Read, 2015)

Diagram: a visual that depicts an object, concept, progress, or idea, in a simplistic manner, usually consisting of a line drawing

Dynamic visualizations: external, interactive, computer-based products that represent and explain scientific phenomena (Linn & Eylon, 2011)

Graphic: visual representation created on paper, the computer, or other surface to communication information provides about a concept, often including numbers, words, and other symbols (Callison & Lamb, 2007)

Grounded theory: a framework in which data is collected and analyzed simultaneously and repetitively such that emerging concepts are used to develop a theory to explain a phenomenon or experience

Icons: the most basic type of sign that relies on physical resemblance to the real object to convey meaning

Inquiry: student-centered instruction that focuses on providing learning experiences that resemble the processes scientists use to gain new knowledge and validate existing knowledge (Zambak, Alston, Marshall, & Tyminski, 2017)

Memos: informal analytical notes used for the elaboration of codes and to note ideas about the data

Mental models: internal representations consisting of images formed by the brain when interpreting concepts, ideas, or principles (Rundgren & Tibell, 2010)

Pedagogical Content Knowledge: the combination of knowledge and sound judgement that is used when making a particular content understandable by others

Phenomenology: an approach to understand the experiences of a group of people in relation to a common event or activity

Representational competence: having skills that are beneficial for creating, interpreting, and using visual representations to aid in communicating and learning a particular discipline (Stieff, Scopelitis, Lira, & Desutter, 205)

Rote activities: instructional activities in which retention of concepts are based on repetition and memorization of facts

Self-efficacy: beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments. Self-efficacy is context specific, meaning the level of perceived ability changes for each person depending on the situation or task

SmartBoard: an interactive whiteboard system comprised of a computer linked to a projector and a large touch-sensitive electronic board displaying a projected image; they allow direct input via finger or stylus so that objects can be easily moved around the board or transformed by the user (Mercer, Hennessy, & Warwick, 2012)

<u>Spatial ability</u>: the ability to discern the location of objects, their shape, and relationship to other objects through mental images (Newcombe, 2013)

<u>Static image</u>: visual images that do not move, such as a photograph

<u>Symbols</u>: abstract, arbitrary signs that rely on social convention for meaning (Homer & Plass, 2010)

<u>Table</u>: data organized in columns and rows to allow the viewer to identify trends, relationships, and patterns

<u>Visualization</u>: the ability, process, and external product formed from the externalization of mental models, with the purpose of depicting and communicating information (Arcavi, 2003).

1.4 Delimitations.

1. This study was limited to teachers at the selected data collection site.
2. All variables not mentioned in this study may be considered beyond the scope of this study.
3. This study was limited to the variables of the selected participants' lesson plans and other planning documents, implementation of the lessons, interviews, classroom observations, and instructional tools and resources.

1.5 Assumptions.

This study attempts to determine the facilitators and barriers of visualization-based instruction within middle school classrooms utilizing the selected classrooms at the research site. It is assumed that the participants in this study provided accurate and honest remarks concerning their experiences, views, and ways in which they plan for and implement instruction. It is also assumed that the information provided through classroom observations is representative of everyday instruction within the selected classrooms.

1.6 Justification.

This study offers several potential benefits, one of which is a better understanding of the factors that influence teachers' planning and facilitation of visualization-based instruction at the middle school level. This information can help outline ways in which the use of visualizations as instructional tools can be integrated into preservice teacher programs, teachers' professional developments, and workshops. Additional knowledge of teachers' experiences with visualizations in the middle school classroom may help schools address the instructional needs of their middle school students. A greater understanding of the impact of visualizations may lead to more effective uses within the classroom and increased student achievement.

Middle school teachers that have a better understanding of the roles of visualization-enhanced instruction will be more aware to ensure that their classroom environment and the intended purpose of visualizations align. By helping teacher acquire the knowledge to foresee potential challenges, they can plan accordingly. These benefits could ultimately lead to increased learning and critical thinking skills and also allow students to apply the use visualizations to real-world scientific situations.

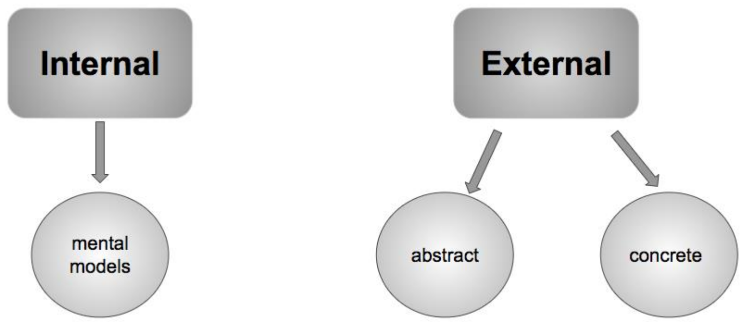
CHAPTER II – LITERATURE REVIEW

2.1 What are Visualizations

Written forms of communication have existed since prehistoric times. Petroglyphs and ideograms have been found throughout Africa, the Americas, Asia, Australia, and Europe (Bland, 2010). Their images have been used to communicate rituals, trace genealogy, and communicate humans' understanding of the universe (Allsworth-Jones, 2017; Martin, 1995). Initial ideograms were series of pictures that represented physical movement. Eventually, ideograms led to the development of logograms with the integration of symbols, such as arrows to indicate direction. Around 3,000 B.C., cuneiforms and hieroglyphs were developed and are considered one of the earliest forms of icons (Seldon, 2013). Although they appear to lack sophistication, they have been effective in communicating messages. Historically, objects such as symbols, tables, diagrams, pictures, and graphs – now commonly categorized as visualizations – have been used to communicate ideas, to indicate the steps in processes, and to entertain.

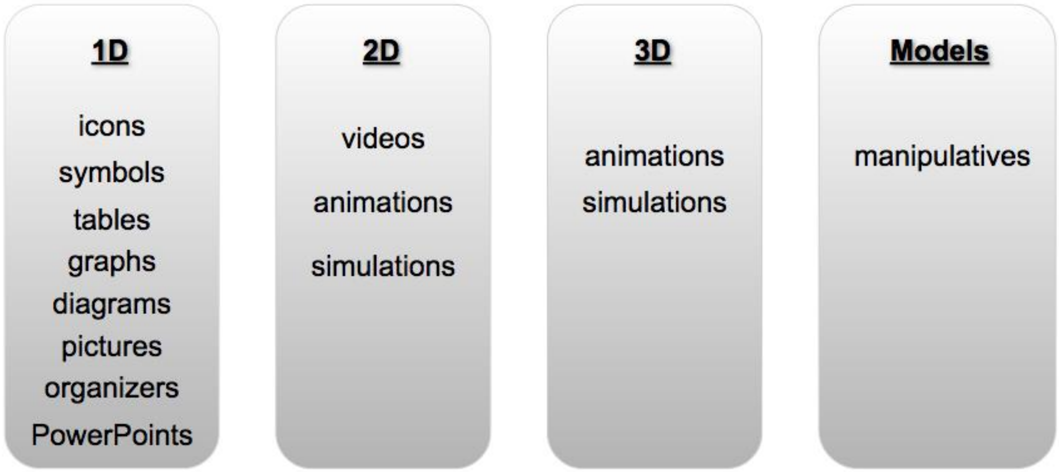
Currently, a common definition for visualizations does not exist. It is common for the term visualizations to be used interchangeable with the term representations. One will find that visualizations and its descriptors can be categorized in a number of ways. The two largest categories used to describe visualizations are internal and external visualizations/representations. Internal representations consist of images formed by the brain when interpreting concepts, ideas, or principles (Rundgren & Tibell, 2010). These types of internal representations are the foundational components of mental models. External visualizations include visual representations that can be seen in the physical world. These visualizations can manifest in the form one dimensional (1-D) objects such as images, tables, diagrams, charts, graphs, photographs, symbols, drawings, and PowerPoints (See Figure 2.1).

Figure 2.1
Categories of Visualizations



They can be two dimensional (2-D) such as videos, animations, and simulations. They may also exist in the form of three-dimensional (3-D) animations. Models, manipulatives, and objects created in virtual reality are also categorized as visualizations. External visualizations represent an individual's attempt to communicate their mental models to others in an organized and concise manner. Majority of the external visualizations have also been referred to as scientific visualizations, as they are commonly used within the field to express scientific concepts and results obtained by empirical research (Rybarczyk, 2011) (See Figure 2.2).

Figure 2.2
Types of External Visualizations



With the advancement of technology, visualizations have been easier to create and use (Ferreira, Baptista, & Arroio, 2012). As a result, professional work has seen a profound increase in the use of visualizations over the past few decades. With the internet making visual images more available, a large portion of information is transmitted by visual stimulation. These advancements have helped make visualizations a common tool in science and science classrooms.

Uses of visualizations are widespread and vary based on the field in which they are used (e.g. science, history, computer programing, art, education). Visualizations are frequently associated with learning new skills, comprehending verbal descriptions, and creativity by linking visual imagery to thinking via reasoning (Gilbert, 2010). In education, visualizations are a central component of the teaching and learning process. They are commonly used to express concepts, steps in a process, directions, relationships between variables, hierarchy and other organization structures, positions, feelings, generalizations, conditions, situations, and explain natural phenomena (Homer & Plass, 2010; Wileman, 1993). Within the scientific world, visualizations need to represent data and communicate findings accurately and effectively (Chang, 2013; Rybarczyk, 2011). However, one of the challenges posed with the use of visualizations is that the person interpreting it must possess the skills needed to unpack the information encapsulated within it.

2.1.2 Types of visualizations

Mental Models. Mental models are internal representations that individuals construct based on their interactions with the external world, mostly through the interpretation of an external representations (Kokkonen, 2017; Rundgren & Yao, 2014). Students construct mental models based on their prior knowledge, ideas, conceptions, or past experiences. These mental models are useful because they allow students to make predictions or explain phenomena or events (Shepardson, Wee, Priddy & Harbor, 2007). How mental models are developed varies with each individual and is based on a method that works best for them (Hilbelink, 2009). These mental models are always under construction and are influenced by new information and past and current experiences (Shepardson et al., 2007). By eliciting students' mental models, educators are able to expose just how multilayered the learning process is (Shepardson et al., 2007). Educators can identify potential impediments to the learning process and gain insight when designing curriculum and planning instruction by having a deeper understanding of students' mental models (Shepardson et al., 2007).

Because students come to science classrooms with different cultural, educational, and personal experiences, each student has different mental models. Learning science, in part, require students to manipulate their existing mental models and use their current state of understanding to develop external models (such as chemical formulas, drawings, sketches, and graphic organizers) (Rundgren & Tibell, 2010). Mayer (1989) lists seven criteria he believes should be contained within instructional materials to help students build appropriate mental models and understand complex systems. According to Mayer, a good model is:

1. Complete- it contains all the objects, states, and actions of the system;
2. Concise- it contains just enough detail;
3. Coherent- it makes intuitive sense;
4. Concrete- it is presented at an appropriate level of familiarity;
5. Conceptual- it is potentially meaningful;
6. Correct- the objects and relations in it correspond to actual objects and events; and
7. Considerate- it uses appropriate vocabulary and organization.

With appropriate mental models, a student is better able to understand causal relationships that exist within a complex system, even if they are not explicitly taught the information.

Concrete and abstract visualizations. In addition to being internal or external, visualizations are characterized as being concrete or abstract. Concrete visualizations have strong resemblances to objects in the real world, such as photographs and realistic drawings. Abstract visualizations show information in a way that does not resemble tangible objects. Rather, they focus on certain aspects of information. Interpreting the meaning of abstract visualizations is often based on the interpretation of conventions, such as arrows in a flowchart or colors used to show altitudes on geographic maps (Prangsma, Boxtel, Kanselaar & Kirschner, 2009). Both concrete and abstract visualizations have advantages and disadvantages. Concrete visualizations place less of a demand on the user than abstract visualizations to interpret its meaning (Prangsma, et al., 2009). However, the value of concrete visualizations is often limited by its reliability, the use of symbols that are specific to a particular period of time, and individuals' experience with visual language in general (Prangsma et al., 2009).

Icons and symbols. Icons can be described as the most basic type of sign that rely on physical resemblance to the real object to convey meaning. Homer and Plass defined symbols as abstract, arbitrary signs that rely on social convention for meaning (Homer & Plass, 2010). The use of icons may be beneficial for learners with low prior knowledge in a subject because icons are easier to understand whereas symbolic representations require knowledge of the field to interpret. The use of abstract concepts and symbols are commonplace in courses such as science, mathematics, information technology, reading, and writing (Brooks, 2009). Using multiple types of visualizations at the same time has been met with mixed results. Research has shown that presenting information in both iconic and symbolic formats is redundant and increases the visual complexity of the display. The combination of both types of visuals hinders learning instead of aiding it (Homer & Plass, 2010). Researchers have also found that adding iconic representations to simulations can enhance learning for inexperienced learners, but may hinder learning for more experienced learners (Homer & Plass, 2010; Rundgren & Tibell, 2010; Zhang & Linn, 2011).

Static images. Text is read in a linear fashion and the reader has to remember details over time in order to make sense of it. As one reads, they have to translate the words into mental images to make meaning of the content (Brooks, 2009). Static images, on the other hand, can be viewed by the learner with little interaction (Homer & Plass, 2010). Static visualizations can be used in the science classroom to help students visualize exemplars, objects, and scientific concepts (Rundgren & Yao, 2014). In many instances, presenting appropriate pictures alongside text increases understanding and memorization (Prangsma et al., 2009).

Concept Maps and Graphic Organizers. Science education research opened the door for the development of concept maps, also known as graphic organizers or thinking maps. A concept map is a two-dimensional graphic or schematic diagram that assists in organizing thoughts, concepts, and recognizing patterns (Lott & Read, 2015). Concept maps often consist of concepts enclosed within nodes and links drawn that clearly identify the relationships between the concepts. Different from a flowchart or an outline, a concept map is usually nonlinear and web-like (Llewelllyn & Johnson, 2008). Concept maps depict a form of hierarchy with nodes playing supporting roles to connecting nodes. Creating and using concept maps allow students to graphically illustrate how components are interrelated and provide them with the opportunity to further develop the concept map by adding links or connecting words to describe the relationship between concepts. After creating a concept map, students are better able to identify patterns, networks, and connections within the systems (Llewellyn & Johnson, 2008).

Like concept maps, graphic organizers also aid students in organizing their thoughts, extracting information from resources, and recognizing patterns. They are often used in science to explain and describe steps in procedures. Graphic organizers help students process information that allow them to link their prior knowledge with new knowledge through visual cues (Mercuri, 2010; Lott & Read, 2015). While research indicates that all students can benefit from the use of graphic organizers, the selection of the most appropriate organizer for the task and consideration of the student's cognitive ability plays a role in its effectiveness (Lott & Read, 2015).

Drawings. A drawing is an externalization of a concept or idea (Brooks, 2009). Drawing is both a means of communication as well as a problem-solving tool. The process of drawing can make one's thoughts more comprehensible and provides a vessel for expressing one's ideas (Baxter & Banko, 2010). In relation to young learners exploring scientific content, drawing has the potential to externalize the expression of ideas and concepts (Brooks, 2009). Unlike oral speech, drawing leaves a permanent record that can be shared again as well as revisited by the originator (Brooks, 2009). In science, drawings are often used to show life cycles, relationships between variables, identify, and label objects (Baxter & Banko, 2018). Through drawing, students are able to visualize what they are thinking. Drawing enables learners to play around with and transform their ideas (Brooks, 2009). This is important because drawing more closely parallels thought than text. When a thought or idea is externalized in the form of a drawing, it is possible to interact with it at interpersonal and intrapersonal levels as well as re-contextualize, revisit, and revise it (Shepardson et al., 2007).

Models. Scientific or conceptual models can be used in science as a simplification of a phenomenon, and used again in the inquiry-process to explain that phenomenon (Rundgren & Yao, 2014). Identifiable as one of three types, physical, conceptual, or mathematical, models play a central role in developing, communicating, and validating scientific knowledge (German 2018; Kokkonen, 2017). Physical models are often used to introduce complex concepts, help students answer initial questions about the content, and develop hypothesis and explanations of scientific phenomena (Kokkonen, 2017). Conceptual models represent abstract concepts and ideas such as the interactions of molecules in chemistry (Kokkonen, 2017). In comparison to the object they represent, models can be scaled such that they are larger than what they represent (such as a virus), smaller than what they represent (such as mountains), or the same size (such as a human torso) (Rundgren & Yao, 2014). When examining their use in the classroom, science models for young learners tend to rely on representations that link concepts to objects at a basic level (Brooks, 2009).

Dynamic visualizations. Dynamic visualizations are external, interactive, computer-based products that represent and explain scientific phenomena (Linn & Eylon, 2011). Dynamic visualizations such as videos, animations, and simulations are often embedded inside daily intsruction to help students visualize complex content, natural processes, mechanical systems, and various kinds of procedures (Spanjers, van Gog & van Merrienboer, 2010). They have an advantage over static images in helping students understand abstract concepts (Rundgren & Yao, 2014). They are also superior in helping students perceive changes over time rather than having to mentally infer them as with static images or text (Spanjers et al., 2010). When determining the effectiveness of dynamic visualizations, factors such as the duration of their use during instruction, they type of concepts they are being used for (e.g. abstract, microscopic, observable processes), whether they are being used as the main source of instruction or playing a supportive role should be considered (Ryoo & Linn, 2012). These factors determine whether the dynamic visualizations will be more effective for learning than static pictures.

Having well-designed dynamic visualizations paired with well planned, inquiry-based activities can significantly increase student learning (Chang, 2013). To achieve this, the content in dynamic visualizations is often broken up into multiple sub-events or sub-steps to prevent a "here then gone" effect (Goff, Reindly, Johnson, McClean, Offerdahl, Schroeder, & White, 2017). This allows students to be introduced to new information, process it, and then be introduced to additional information all while focusing the students' attention to the key aspects. (Spanjers et al., 2010). To help students retain the concepts being covered, information from the dynamic visualizations must be maintained and processed in working memory. However, this can cause a bottleneck effect for the learning process, due to the limitations of the working memory (Spanjers et al., 2010).

Animations. Animations explain dynamic, evolving processes through a rapid sequence of pictures of movement and simulation that are displayed on a computer-based screen (Aksoy, 2012). They are superior at displaying and simplifying procedural information and sequences that are difficult to interpret through text alone (Cheon, Chung, Crooks, Song & Kim, 2014). They can be interactive, requiring input from the user, or non-interactive and used as instructional movies to illustrate events or concepts (Rundgren & Tibell, 2010). Animations have been acknowledged with being more effective that static images in helping students develop accurate mental models (Cheon et al., 2014). Because of the dynamic nature of animations, the learning around the animation must be specifically structured with the students' needs and skills in mind in order for the animation to serve in a beneficial capacity. These structures should include short sequences that allow students to process information in segments before receiving new information (Rundgren & Yao, 2014). Research indicates that a learner's spatial ability determines how effectively they can make use of external animations to alter their own mental representation of the same object, often making the mental representation more accurate (Lin & Dwyer, 2010). Students with a greater level of representational competency will exhibit higher levels of spatial abilities and are more likely to benefit from animations than those with low-level spatial abilities because of the degree of cognitive processing required when using animations. (Huk, 2006; Lin & Dwyer, 2010).

When used with learners with low representational competency who lack high spatial ability, animations can be coupled with interrogative cues and other forms of segmentation such as guided questions and asking students to recall prerequisites prior to viewing the animations. (Lin & Dwyer, 2010). Students with greater prior knowledge can focus on relationships between the concepts being shown as oppose to focusing on the surface level of the images (Goff, Reindl, Johnson, McClean, Offerdahl, Schroeder, & White, 2017). These instructional strategies help integrate the previously learned information with new information (Lin & Dwyer, 2010). To further assist students in utilizing and processing the content in animations, learners should be given some control over the pace of the animations (Spangers, van Gog & van Merrienboer, 2010).

Simulations. Simulations allow learners to explore phenomena and their dynamic properties through the manipulation of technology-based or real world models (Homer & Plass, 2010). In most cases, the user selects values that are inserted into the simulation and observe the results as output variables (Rundgren & Tibell, 2010). Studies of the use of simulations at the secondary level show that they are ideal tools to teach students how to collect, analyze, and communicate data (Allan, Erickson, Brookhouse & Johnson, 2010). Because of the degree in which the user can control both the input and the output of simulations, they are considered one of the most powerful multimedia tools available (Ferreria, Baptista, Arroio, 2013). As with the other types of visualizations, some researchers found that simulations can add to the complexity of a learning situation by creating a higher cognitive load, particularly for inexperienced learners (Homer & Plass, 2010).

Research has shown that science visualizations are most effective when the cognitive and affective needs of the target audience are taken under consideration (Homer & Plass, 2010). Forming a match between representation type and the learner should occur prior to implementing instruction. Materials that are ill-matched can hinder learners with both low and high levels of prior knowledge (Homer & Plass, 2010). Therefore, as it relates to middle school learners, classroom visualizations should be designed and utilized to best support the ages and different levels of the learners' prior knowledge (Homer & Plass, 2010).

A dual-coding learning theory that involves verbal and visual stimuli working together cognitively to enhance understanding is supported by researchers. The positive effects of visualizations are often explained by this theory, which indicates that information is processed through one of two channels- verbal or visual- and points out that adding pictures to text will benefit learning in most cases. It is through the strategic integration of verbal or visual stimuli with pictures and text that some learners are able to absorb information more effectively (Taylor, Pountney & Malabar, 2007). This is also one of the premise of teaching and learning through differentiated instruction. Multiple representations of a problem can help learners understand new concepts and build connections among the representations (Taylor et al., 2007). There are important factors to consider which may enhance learning with visualizations. These factors include whether learners can follow the engagement of the visualization and construct knowledge through the use of the visualization itself or through the addition of clarification activities. In addition, learners will need to modify their mental models and integrate the new knowledge with their existing knowledge (Chen, Hong, Sung & Chang, 2011).

A learner's developmental state has an effect on how visualizations are interpreted. Executive function, which allows learners to plan, monitor, and evaluate their own behavior, peaks around age fourteen. This suggests that there should be differences in learning that are independent of prior knowledge for students who are younger than fourteen compared to students who are older than fourteen (Homer & Plass, 2010). Typical middle school students' ages range from twelve to fifteen and if functioning on grade level, studies indicate that students may not have the cognitive controls to process visualizations until their eighth grade year. Yet, visualizations such as static images, models, videos, and animations are heavily embedded in educational and entertainment settings for children as young as three to six months old. (Chen et al., 2011).

2.1.3 Cognitive Load Theory

Cognitive Learning Theory (CLT) distinguishes three types of cognitive loads: intrinsic load, extraneous load, and germane load, and their interactions between the working and long term memories (Ayres & Pass, 2012). The theory looks specifically at the processing mental load placed on a learner during instruction. Intrinsic load can be measured by the degree of interactivity with the new content, and the amount of interaction required between the material being learned and the learner. The higher the number of informative elements and the interactions between them, the higher the intrinsic cognitive load and the more difficult the material is to learn (Spanjers et al., 2010). Intrinsic load cannot be directly manipulated by instructional designers because it results from the nature of the instructional material. Material that contain more complex or abstract information usually induces a higher intrinsic cognitive load because it requires more mental effort to integrate the mental resources to make comprehension and acquisition of new knowledge possible (Lin & Dwyer, 2010).

Learning new information involves the construction of cognitive schemas in which the mind determines patterns and organizes information into categories and relationships. Therefore, the design of instructional tasks play an important role in the depth of cognitive demand placed on a learner. The level of extraneous cognitive load is determined by the format and manner in which the instructional material is presented and by the amount of working memory that is used when learners engage in instructional activities (Lin & Dwyer, 2010). Insufficient or poorly designed activities can compromise potential learning by increasing cognitive overload (Sweller, 2010). Instruction that contain components that are lengthy, extremely rigorous, or contain large amounts of verbal information can also impose an extraneous cognitive load (Leah & Sweller, 2016). However, known information can be reorganized by the brain through an unlimited number of combinations to create new knowledge. When the working memory processes familiar information, the demand placed on the working memory decreases (Paas & Ayres, 2014). Therefore, learners with high levels of prior knowledge experience less cognitive loads compared to learners with low levels of prior knowledge, when completing instructional tasks (Ayres & Pass, 2012). For learners with low levels of prior knowledge, new incoming information needs to be processed while maintaining the previously presented information (Spanjers et al., 2010). Cognitive activities that cause extraneous loads for students reduces the time available for maintaining and processing activities.

Germane cognitive load refers to the resources and processes the working memory uses when dealing with an intrinsic cognitive load (Meissner & Bogner, 2013). Both extraneous and germane loads can be controlled and manipulated by instructional designers. Since the working memory of humans is limited in its capacity, the total amount of the intrinsic, extraneous, and germane loads should not exceed working memory limits (Lin & Dwyer, 2010). According to Paas and Ayres (2014), the working memory is able to perform in constructs that analyze an average of four elements of information at once for a duration of thirty seconds per increment of processing time.

Teachers should be aware of the cognitive loads instructional materials may impose on learners. The working memory has a limited capacity when processing new information and certain types of visualizations can impose a greater strain on the working memory (Leah & Sweller, 2016). For example, dynamic visualizations, such as animations, could pose extraneous cognitive loads due to their transient nature (Ayres & Paas, 2012; Cheon et al., 2014; Spanjers et al., 2010). In order for them to be effective instructional aids, the information they provide must be quickly processed by the working memory and the learner must then be ready for new information. The constant cycle of processing, storing, and preparing to process new information within a small amount of time can result in inhibitions to learning or stagnate learning. This effect can be alleviated when cueing or segmentation of the information is done (Ayres & Paas, 2012). Therefore, on complex dynamic visualizations that are high in intrinsic load, the extraneous load should to be decreased as much as possible so that learning will not be hampered (Spanjers et al., 2010).

2.2 Middle School and Trends in Middle School Teaching

Early adolescence describes the range of time when children are between the ages of eleven and fourteen. During this time, their overall emotional state of being can become less positive and more variable. Adolescents are more likely to experience increased peer associations and frequent changes in friendships. Peer harassment and relational aggression can occur as adult supervision decreases as the child learns to become more independent (Rusby, Crowley, Sprague & Biglan, 2011). This age group can also exhibit characteristics of being easily embarrassed, insecurity, anti-socialism or oversocialism, rebellion, and extreme self-consciousness (Rose, 1999). Harraldson, Lindgren, Mattsson, Fridlund, and Marklund (2010) states that these ranges in emotions makes students within this age range extremely sensitive and vulnerable.

The middle school platform evolved in the early 1960s after the realization that adolescents have unique needs. The development of the middle school system showed a shift in the desire of educators and stakeholders to support the diverse needs of this age group. Studies of this age group identified several developmental needs which included: 1) competence and achievements, 2) meaningful participation in social groups; 3) creative expression; 4) opportunities for self-definition; 5) positive social interactions with peers and adults; 6) physical activities; and 7) structure and clear limits. (Rose, 1999). Wu-Rorrer's (2017) research addressed how the middle school environment evolved from its initial vision of the sixties. Currently, the time students spend in middle school has become personalized school environments that offer cooperative social interactions, context-based learning, and opportunities to learn content through real world problem solving (Wu-Rorrer, 2017). Therefore, acknowledging the multitude of factors effecting the middle school child, it is important that middle school teachers adopt the strategies that best support the needs of their students.

In addition to focusing on student achievement, the middle school teacher must also be aware of the sensitive needs of his/her students. For many teachers, juggling the skills needed to be an effective instructor, managing the classroom environment, meeting the expectations of their school and district, and servicing the social and emotional needs of students can be challenging. Research indicates that teachers should have a deep understanding of science concepts and be able to identify and explain those concepts to their students (McConnell et al., 2013). Effective teachers are aware of a variety of strategies so that effective instruction can be delivered, positive student-teacher interactions can be formed, and a classroom climate can be developed (Armstrong, 2006). This is important because how content is conveyed to students not only play a role in their interest level in the subject but also sends a message about which topics are most important (Shulman, 1987).

Grades six through eight play an important role in helping students meet science goals. This is based on the density of new content addressed in middle school, the introduction to new scientific approaches such as laboratories, and a focus on science as a discipline (Yager & Akcay, 2008). In the middle school sciences, often there is an attempt to focus on school and community problems such as global warming, nutrition, space travel, and disease. Unlike elementary school students, who usually have one or two teachers who provide instruction in all subjects, most secondary students have a different teacher for each subject. Successful middle schools have characteristics in common which include a small community feel, classroom layouts that more closely resemble high school classrooms than elementary classrooms and are student-centered (Alvarex, McHatton, Farmer, Bessette, Shaunessy-Dedrick, & Ray, 2014). There is often a group of teachers who work together as a team that provide instruction to no more than 100 students. This team of teachers strategically integrates developmental appropriate social and cognitive tasks into their lessons (Armstrong, 2006). Grading periods vary but are either six to nine weeks per period (Yager & Akcay, 2008). At the middle school level, students must adjust to a greater number of teachers who have varying requirements, expectations, and instructional styles.

Researchers have found that schoolwork typically found in middle school does not provide enough cognitive challenge for young adolescents (Conklin, Hawley, Powell & Ritter, 2010). A majority of teachers used traditional lecturing methods in class (Hardin, 2009). Additional research shows that students were memorizing “disconnected” facts and failing to develop the critical-thinking skills, problem-solving skills, or the ability to relate these facts to real life (Hardin, 2009). Educators and parents alike generally agree that rote memorization is not an effective way to comprehensively teach science. However, given the increasing curriculum demands, larger classroom sizes, and a greater focus on student performance on standardized tests, the prevalence of inferior teaching strategies has not decreased. Research also indicates that students at the middle school level have difficulties with inquiry-based activities, such as asking questions based on scientific merit, deciphering between relevant and irrelevant evidence, and drawing conclusions based on data collected (Hardin, 2009).

To hone their skills, teachers need to: 1) develop a particular vision of teaching practice; 2) possess an understanding of their subject matter, learners, and modes of instruction; 3) understand the conceptual and practical tools for teaching; 4) identify with particular dispositions; and 5) possess a set of practices that will enable them to enact their vision of good teaching (Conklin et al., 2010). As such, teachers often require extra training in order to provide developmentally age-appropriate scaffolding, the basic foundation needed for learning activities (Hardin, 2009). Not only are the teachers' skill deficiencies a factor in effective teaching, time constraints are another issue that many teachers feel deters them from certain activities, such as inquiry-based activities (Hardin, 2009).

To meet the needs of middle school students, teachers need not only a strong conceptual understanding of their content area content but also a strong understanding of young adolescents' capabilities, curiosities, and prior knowledge (Conklin et al., 2010). Factors such as teacher educational background, both the teachers' and students' beliefs about teaching and learning, the teacher's role in the classroom, the perceived level of student ability, and the importance of the subject-based topics all play a critical role in what goes on within a classroom (DiBase & McDonald, 2015; Gee & Gonsier-Gerdin, 2018; Gess-Newsome & Lederman, 1999). Unfortunately, studies have shown that many secondary teachers prepared in secondary teacher education programs hold low expectations for the kind of intellectual work middle school students can accomplish (Conklin et al., 2010). In general, the more complex the strategy, the deeper the processing the learner must utilize and the less likely middle school teachers believe students are capable of reaching the goal (Slater & Horstman, 2002).

Quality instruction should involve students actively constructing of knowledge through challenging tasks that require them to develop reasoned conclusions, interpret primary sources or evidence, and construct informed arguments (Conklin et al., 2010). Tasks like these require a deep factual and conceptual knowledge base but also utilizes students' higher order reasoning capabilities to analyze, evaluate, interpret, and synthesize information (Conklin et al., 2010). Research indicates the prevalence of the lecture, recitation, and round-robin reading in classrooms which reduces student engagement and decreases opportunities to engage in instruction that fosters thinking and transforming information so that it has meaning and understanding (Blanton & Taylor, 2007). Also, research done by Langer found that typical classroom instruction in low-performing schools failed to engage students in collaborative activities, provided few opportunities for group discussion, and failed to focus on developing understanding of material read (Blanton & Taylor, 2007). Instruction of this kind leads students to develop what is referred to as incomplete or "fragile knowledge" (Blanton & Taylor, 2007).

So many factors influence what the instructional time looks like in a typical middle school science classroom. These include state science standards, the instructional material adopted and provided by the school district, additional resources that the teacher has acquired, local and national curricula, in additional to the teacher's knowledge and beliefs (National Research Council, 2012). These factors can sometimes squeeze teachers into a "one size fits all" type of instructional mindset. Research shows that students performing on differing levels require different amounts of time to conceptually dissect concepts or students may need varying amounts of instruction based on their prior knowledge and cognitive load capacity (Daniel, 2018; Odom, Stoddard & LaNasa, 2007). Using the "one size fits all" instructional model, teachers may discover pockets of students within the classroom completely unengaged or less engaged than desired (Odom et al., 2007). Research reveals that teachers must actively participate in planning, development, assessment, and modification of their school science program to be most effective.

Extant literature documents the strong, positive relationship of student-centered teaching practices, attitudes, and achievement (Odom et al., 2007). Active learning changes the role of the teacher to one of tutor, guide, and partner in the learning process as oppose to lecturer (Doppelt, Mehalik, Schunn, Silk & Krysinski, 2008). Traditional teaching practices such as copying notes from lecture or learning scientific terms without context provide poor learning opportunities and are inconsistent with best practices for science, yet they dominate classrooms (Odom et al., 2007). Rote learning is an arbitrary, verbatim, non-substantive incorporation of new ideas into cognitive structure (Odom et al., 2007). Most of the science curricula implemented in the United States are scripted-inquiry rather than authentic inquiry. With scripted inquiry, teachers set the goals, ask the questions, provide the materials, and supply students the "correct" answers and the "correct" conclusion (Doppelt et al., 2008). Rote learning may cause interference with previous learning, and may result in difficulties with patterns of recall, including misassociations (Odom et al., 2007).

2.3 Pedagogical Content Knowledge

Teacher effectiveness as a whole is greater than the teachers' depth of content knowledge or pedagogical background when considered in isolation. Pedagogical Content Knowledge (PCK) is the result of a myriad of research that explains the impact of teachers' beliefs, backgrounds, knowledge, value, and attitudes on instruction development and delivery. PCK can be defined as the combination of knowledge and sound judgement that is used when making a particular content understandable by others. PCK has emerged as a popular and useful conceptual tool for explaining and analyzing the knowledge that teachers use to transform subject matter for student learning (McCaughtry, 2004). Developed and initially published by Shulman in 1985, it is a platform that brings understanding and rationale to the collective skills that teachers possess. This platform of understanding is designed through the lens of teachers' understanding of the curriculum, content, and pedagogical knowledge as it relates to how students learn. It also considers the skills teachers need to be able to relate to students, empathize with their life circumstances, read their emotional engagement with subject matter, and understand the social dynamics of the classroom (McCaughtry, 2004). The foundation of PCK is based on teachers having a thorough understanding of how these various components synergistically aid in the delivery of effective instruction (Shulman, 1987).

PCK evolved from studies conducted by Shulman in which three types of content understanding and their impact on classroom instruction were analyzed: (1) subject matter knowledge; (2) pedagogical knowledge; and (3) curricular knowledge. In 1986, the three categories were refined to subject matter knowledge, curricular knowledge, and pedagogical content knowledge (Gess-Newsome & Lederman, 1999). A year later, PCK was removed as a subcategory describing teachers' content understanding. It became one of the main knowledge components teachers needed to form the basis of quality instruction. The other components are:

- content knowledge,
- general pedagogical knowledge,
- curricular knowledge,
- knowledge of learners,
- knowledge of educational contexts,
- knowledge of the philosophical and historical aims of education, and
- pedagogical content knowledge.

Of these, pedagogical content knowledge was said to have the greatest impact on the classroom (Gess-Newsome & Lederman, 1999). Since its development, it has been widely used in science and mathematics research as a theoretical framework (Scharfenberg & Bogner, 2016).

Gess-Newsome has developed PCK further into two models with subtle but important differences. She has developed a continuum in which on one extreme, teacher knowledge can be best explained by the intersection of their subject knowledge, pedagogy, and content. This model is called the Integrative Model. With this model, the three individual components are still clearly distinguishable although the effect of their integration can be observed. The other end of the continuum represents a new type of knowledge that is developed by the overall effect of blended understanding of subject matter, pedagogy, and contextual knowledge. This "new" knowledge, is referred to as the

Transformative Model, and according to Gess-Newsome, this end of the continuum represents the only form of knowledge that impacts teaching. With the Transformative Model, individual knowledge components are not distinguishable, only the new knowledge. Research conducted on the Transformative model yielded findings that suggest having a strong science background and some or none of the other knowledge components did not always correlate with a high level of PCK (Scharfenberg & Bogner, 2016).

Content specific pedagogical knowledge is accumulated through reflection, active processing, and the integration of its two components- general pedagogical knowledge and personal pedagogical knowledge (Gess-Newsome & Lederman, 1999). General pedagogical knowledge is composed of knowledge based on research and scholarly literature on classroom organization and management, instructional models and strategies, and classroom communication and discourse. General pedagogical knowledge is typically developed during education classes in teacher preparation programs (Gess-Newsome & Lederman, 1999). In the classroom, this knowledge is combined with personal content knowledge which is based on personal beliefs and perceptions about teaching (Gess-Newsome & Lederman, 1999). A critical component of the development of pedagogical knowledge, whether general or personal, is teaching experience. The combination results in the development of context-specific pedagogical knowledge which assist teachers in decision making and contribute most directly to PCK (Gess-Newsome & Lederman, 1999).

Pedagogical Content Knowledge is inseparable from knowledge about evaluation and assessment procedures. Studies have confirmed links between teacher behaviors as it relates to general pedagogical knowledge and student achievement (Gess-Newsome & Lederman, 1999). Research has implied that students learn best from teachers who spend most of their available time focusing on content, who provide students with learning activities that are appropriate for their level in terms of difficulty, and who maintain momentum in the pacing of instruction. Students respond favorably to active teaching when the design of the instruction provides structure. Other actions such as clear presentations, planned redundancy, and adequate wait-time for student response are also factors which benefit student learning (Gess-Newsome & Lederman, 1999). Students learn more efficiently when the teacher structures new information, relates it to prior knowledge, monitors performance, and provides adequate feedback, all of the aforementioned characteristic elements of PCK (Gess-Newsome & Lederman, 1999).

Other factors which may influence a teacher's decision or ability to use the knowledge that is generally available is the student's level of cognitive awareness, the complexity of teachers' knowledge structures, and the extent of teachers' personal experience (Gess-Newsome & Lederman, 1999). Teachers' understanding of how students learn and being well-versed in one's discipline can yield such benefits as:

- increased accuracy in the information provided by teachers,
- students able to make more cross-curriculum connections,
- content presented in appropriate vertical progressions,
- content and learning tasks well matched with the students' cognitive abilities,
- teachers more aware of students' prior knowledge and skills,
- teachers who are able to deviate from lesson plans when appropriate, and
- teachers are able to use fewer and deeper learner tasks (McCaughtry, 2004).

Skilled teachers use a range of management techniques and possess the knowledge-base to know under which circumstances a given technique might be best to promote student learning (Gess-Newsome & Lederman, 1999).

Teacher's personal pedagogical knowledge is developed based on two important components: personal beliefs and perceptions of teaching and learning, and personal practical experience working in a classroom (Gess-Newsome & Lederman, 1999). The personal beliefs teachers bring to their classrooms are rooted in how they personally viewed their own classrooms and their own experiences as a student (Gess-Newsome & Lederman, 1999). Research shows that these views are difficult to change (Gess-Newsome & Lederman, 1999). Teachers are not likely to implement curriculum materials that contradict their ideas about content, how that content should be taught, and their views about teaching and learning (Gess-Newsome & Lederman, 1999). Experienced teachers hold tightly to techniques and methods that have worked well for them in the past, valuing these materials for their pedagogical efficiency and ease of implementation (Gess-Newsome & Lederman, 1999).

2.4 Grounded Theory

Using PCK as a starting point, grounded theory conceptual framework and methodology was used to guide the development of a new theoretical framework. Even though teachers were expected to execute effective pedagogical strategies in the classroom, many factors determined how the planned instruction was delivered and whether it was modified. The dynamics of these two factors determined how students learned. Through the use of grounded theory, this project sought to gain a better understanding of teachers' experiences with visualizations as an instructional resource.

Sociologists Barney Glaser and Anselm Strauss developed grounded theory as a foundation for qualitative research during their study of dying in hospitals in 1967 (Charmaz, 2006). It is a distinct type of qualitative research that provides specific guidelines for a methodology used to analyze the data through an intensive inquiry process, steps that should be following during data analysis, and the final product of the research (Charmaz, 2006; Charmaz, 2008). Glaser and Strauss's work on grounded theory was the first to explain how theories evolved based on pre-existing research as opposed to the typical method that used new research to test the hypothesis of existing theories. (Charmaz, 2006). When using grounded theory, the researcher uses data collection and analysis that are specific to qualitative studies to generate a theoretical explanation for a specific phenomenon (De Chesnay & Banner, 2015). The process is described in detail in their book, *The Discovery of Grounded Theory*. Since its development, grounded theory has become a commonly used methodology for qualitative research (De Chesnay & Barner, 2015).

Grounded theory is both a method for understanding research participants' social constructs and a method used by researchers to identify trends through inquiry (Charmaz, 2008). The practices of grounded theory are executed on the platform that the data is continuously analyzed as it emerges and what emerges plays a significant role in the direction in which the study moves. In addition, this data, which is grounded in the heart of the study, is used to create classic examples (Glaser & Strauss, 1967). As data is collected, it is coded and analyzed inductively to determine emerging themes. As themes emerge, hypotheses are made, additional data is collected and analyzed deductively. This process lays a supporting foundation for the hypothesis. Ultimately, the researcher, who does not enter the field with a preconceived notion of how to explain the phenomenon or the associated theory, develops a theory that explains the phenomenon which has been observed (Weed, 2009). The goal is to construct abstract theoretical explanations for social processes (Charmaz, 2006).

The methodology focuses on identifying the meanings of events for specific individuals. Because it is based on the research subjects' personal experiences, the overall meaning is developed and modified based on the interactions of the research subjects (Harraldson et al., 2010). These meanings can then be theorized and applied to future events and situations (Strauss & Corbin, 1998) This allows the theory to be composed of symbolic interactions and used to study social processes (Harraldson et al., 2010).

A definitive characteristic of grounded theory is the development of a theory that emerges from iterative comparisons and is embedded in the data. Grounded theory is wrapped within a repetitive process of collecting data, analyzing it, and comparing it with the literature (Weed, 2009). Afterwards, additional data is collected to confirm the previous step and to hone the preceding data collecting processes (Weed, 2009). Grounded theory primarily involves the generation of theory by induction but is the overall result of a tedious relationship between inductive and deductive data analysis. Recent researchers have termed that back and forth process of data analysis as abduction (Weed, 2009). This cycle repeats until the point of theoretical saturation (Weed, 2009). Blarney describes it as a rigorous method woven together by constant comparisons and conceptualizations (Glaser, 2002). The complete process along with the developed theory helps identify the social processes under study (Harraldson et al., 2010). The foundation of grounded theory allows itself to be spread across a multitude of research methods, including, but not limited to, experiments, surveys, content analysis, and quantitative methods. All of which accepts data without prejudice (Glaser, 2002).

After Glaser and Strauss's development of grounded theory, their viewpoints began to diverge. Glaser's view remained consistent with the original work in that the process of coding and categorizing data revealed gaps that should be further explored as the research continued (Kenny & Fourie, 2015). Through data analysis, data was analyzed line by line and coded, core categories emerged, additional data collection made the supporting data for these codes denser, and from that a grounded theory emerged (Kenny & Fourie, 2015). Glaser emphasized allowing concepts to emerge without being forced or propelled by a preconceived mind (Age, 2011).

Glaser categorized three important characteristics of conceptualization. The first was the organization of categories and properties into emergent concepts that are abstract- devoid of time, place, and people. The second was that these concepts should have an enduring hold on its audience (Glaser, 2002). The third was the abstractness of the concepts- striped of person, time, and place (Glaser, 2002). Glaser identified a concept as an emergent social pattern grounded in data (Glaser, 2002). These concepts emerged from the constant comparison of data and their emergent categories. These categories became apparent after careful analysis of theoretical samples when the data reached a point of theoretical saturation. During the analysis process, it was critical that the researcher allowed the categories to emerge on their own and not force them out or to assume their existence prematurely. (Glaser, 2002). Glaser pivoted his argument on the researcher's ability to develop a theory based on a core variable which can be relevant to any time or place (Glaser, 2002). People were not labeled and categorized, the behaviors were (Glaser, 2002).

Strauss, on the other hand, offered a series of tools and procedures for constructing the theory from the data (Age, 2011). Strauss emphasized a methodology which led to verification, then went on to develop his version of grounded theory with Juliet Corbin (Charmaz, 2006). By 1990, Strauss began to coauthor research and other publications with Corbin, one of which is a book titled *The Basics of Qualitative Research: Grounded Theory Procedures and Techniques.* Strass and Corbin's version of Grounded Theory focuses on coding with structure as a major component of allowing the grounded theory to emerge. Their process involves a four-step coding process (open coding, axial coding, selective coding, and conditional matrix) that allows the researcher to create, rather than discover a theory that closely aligns with the data (Kenny & Fourie, 2015). Strauss and Corbin have defended their work by arguing that although the coding process is more strategic, it is flexible and necessary to rid the researcher of their own prejudices and preconceptions (Flourie, 2015). Glaser claimed that Strauss and Corbin failed to develop their theories in abstractness; therefore, it suggests researchers force descriptions into their theories (Glaser, 2002). Since this time, grounded theory has been tweaked by researchers (Moore, 2009). Many researchers have adopted and adapted grounded theory methodology to fit a variety of ontological and epistemological positions, such as constructivism, feminism, critical thinking, and postmodernism (Mills, Bonner, & Francis, 2006).

Kathy Charmaz, a former student of Glaser and Strauss, published work which depicted another variant of the grounded theory process. Charmaz's version of grounded theory contains many of the classic components of grounded theory, including memo writing, comparison of data, theoretical sampling, and saturation to the point where no new data emerges. Her version allows the research to be more flexible and imaginative until themes emerge (Kenny & Fourie, 2015). Her version also places a heavier precedence on intensive interviews to draw a closer connection between the data and the meanings participants assign to their experiences (Kenny & Fourie, 2015).

Charzman describes grounded theory as a systematic yet flexible set of guidelines for collecting and analyzing qualitative data to construct theories which are grounded in the data from which it was collected (2006). It is a set of guiding principles for conducting research instead of strict rules that must be followed in a prescribed method (Charmaz, 2006).

Seven defining components of grounded theory was developed by Charmaz based on the work of Glaser and Strauss. They include:

- the simultaneous process of data collection and analysis;
- the development of analytic codes and categories based on the data instead of preconceived logically deduced hypothesis;
- constantly comparing the data against itself at each stage of the research process;
- advancement of the developing theory at each step of data collection and analysis;
- the writing of memos to elaborate on the categories;
- theoretical sampling; and
- conducting the literature review after developing an independent analysis.

After the data collection, the second characteristic is the development of categories and the third is the consistent nature of comparing categories until the multiple categories converge into one theory. Grounded theory requires the researcher to begin analyzing the data as it is collected to start the process of identifying commonalities and relationships through coding (Charmaz, 2006). The process of grounded theory begins with data that is constructed through empirical means such as observations, interactions, and artifacts surrounding a particular phenomenon (Charmaz, 2006). Interview methods associated with grounded theory may differ from other qualitative forms in that grounded theory interviews narrow of the scope of topics visited in order to gather specific data for framework development (Charmaz, 2006). The goal is to explore rather than interrogate (Charmaz, 2006). Grounded theory gives the researcher the freedom to follow-up on data, intuitions, thoughts, and hunches but offer guidelines on how they might proceed (Charmaz, 2006).

Categories are representative of patterns which are strategically named based on the entitlement that best fits the group of information. They are developed by examining the data (Glaser, 2002; Glaser & Strauss, 1967). This is one manner in which validity is achieved- by ensuring that categories are grounded in the data. Equally, it should be understood that Glaser also insists that the concepts are “in vivo,” meaning coming directly from the data, in other words, from the words of the participants (2002).

On the contrary, Glaser does not suggest member checking as a method to allow participants to double check the theory or much of the final categories leading to theory development. Glaser warns that participants may be unfamiliar with the data in its entirety, may be unable to interpret the data as a whole, or may approach the data with disdain (Glaser, 2002). The developed theory should be clear enough that future categories can be verified. In order for this to occur, the initial theory should be built based on systematic discovery and data analysis (Glaser & Strauss, 1967).

Prior to the development of grounded theory, traditional qualitative research had roots in Enlightenment values dating back to the eighteenth century. These values included beliefs in reason objectivity, scientific authority, and notions of progress through science. Qualitative studies, in general, are heavily associated with time, place, people, and other descriptive characteristics of each particular study (Glaser, 2002). Before the work of Corbin and Strauss, qualitative studies focused primarily on verifying existing theories with new research. Qualitative studies are known to paint a clear and vivid picture of the research environment and the individuals (Glaser, 2002). However, while mostly associated with qualitative studies, grounded theory is categorized differently for qualitative research in that its concepts are devoid of these heavy descriptions (Glaser, 2002). Grounded theory became known as the most realist and positivist of the modernist qualitative methods (Charmaz, 2008). This renders the theory more applicable to any relevant time, place, or group of people and allows itself to be constantly modified with the addition of substantive data (Glaser, 2002). Its approach is flexible enough that it works well alongside other approaches to qualitative research and not conflict (Charmaz, 2006).

When collecting data, Charmaz suggests that the researcher ensures data collected is rich and thorough. She also suggests that data is placed in relevant situational and social context early in the analysis process (Charmaz, 2006). While going through the process of data comparison and analysis through coding and memo writing, the researcher shapes and reshapes the data collection process, thus, leading to refined data collection and theoretical sampling. In short, the primary goal of grounded theory is to seek data, describe observed events, answer fundamental questions about the event, then develop theoretical categories to understand it (Charmaz, 2006).

Coding is a process of tagging snippets of the data according to what major theme is associated with that piece of evidence. Coding helps facilitate the comparison of data snippets through the thought process so that code comparisons can be made and the next steps in the field can be determined. Coding also helps facilitate the comparisons of codes against one another. Such comparisons are notated on what is called memos. Memos may also be reflections of thoughts and ideas regarding what may be occurring as revealed by the data.

Memos are informal analytical notes used for the elaboration of codes, to note ideas about the data, and identify possible connections between the empirical world and the emerging theory. Memo writing assists the researcher in the analytical processes. This is the iterative process by which the data and codes builds upon one another. It depends on frequently checking the data's relevancy against additional, new data (Charmaz, 2006). Memos provide ways to explore the data via codes and help shed light on how additional data should be collected (Charmaz, 2006).

The theory produced is referred to as a substantive theory in that it is applicable to specific areas. However, a substantive theory can be developed into a formal theory which allows the theory to be applicable to understanding problems in multiple substantive areas. Each substantive area in which the theory was used would also help to further refine it (Charmaz, 2006). Glaser and Strauss indicated that generating a theory from data means that the hypothesis and concepts are systematically derived from the data during the research, as a result, more emphasis is placed on the research as a process and not merely an end product (Glaser & Strauss, 1967). Their theories are not derived from prior assumptions but from the current process of data collection and analysis (Glaser & Strauss, 1967).

2.5 Pilot Paper –Middle School Teachers' Experiences with Visualizations

2.5.1 Purpose

At the middle school level, it is important that teachers utilize effective teaching strategies to ensure students develop a thorough understanding of science content and phenomena. Visualizations have been heavily used throughout the science community as a tool to aid in the communication and understanding of the sciences. While much of the literature on visualizations is concentrated in the sciences, their use as instructional tools across all levels of education is not well documented. The purpose of this study was to explore ways in which middle school teachers used visualizations in the classroom and to determine what influenced the use of visualizations by middle school teachers.

2.5.2 Conceptual Framework

Visualizations have been used as a categorical term for objects such as tables, diagrams, graphs, animations, and simulations (Gilbert, 2005). The development and use of models and visualizations, also referred to as visual representations, aid in understanding the content along with relationships, causes, and effects in a simplified manner (Gilbert, 2005). Because of this, the development and use of visualizations are crucial in the production of knowledge and can be used to help students succeed at the middle school level.

The conceptual framework for this study was visualization-based pedagogical teacher content knowledge (V-PCK). The V-PCK framework was built on the belief that effective teaching involves an aggregation of knowledge, skills, understanding of Pedagogical Content Knowledge (PCK), and effective knowledge and use of visualizations (Shulman, 1987). V-PCK derived from the more common framework: pedagogy, content, and knowledge, which advocates that teaching requires basic skills, content knowledge, and general pedagogical skills (Shulman, 1987).

2.5.3 Literature Review

Visualizations may include items such as icons, graphs, maps, and mechanical drawings (Tversky, 2005). Because of the limitations of static diagrams, over time, visualizations expanded to include such things as animations and cartoons, 3D products, computer simulations, manipulatives, and some hands-on activities (Tversky, 2005). While there are numerous types of visualizations, most are designed to convey a process or function (Tversky, 2005). Because visualizations are so heavily intertwined within the work and communication of professionals, visualizations have also made a profound entrance into education. Therefore, teachers must understand the nature and significance of visualizations and the role they play in their chosen subject (Gilbert, 2005).

Education researchers have devoted considerable effort to the refinement and implementation of visualization tools for students because of the important role they play in building students' representational competency and aiding in understanding, manipulating, and communicating data (Stieff et al., 2005). Many school districts across the country are looking for ways to increase rigor in the classroom and make teaching and learning a more successful process (Laughksch, 2000). Visualizations could play an essential role in achieving these two goals. Advocates for the use of visualizations can be found among teachers at all levels. High school teachers report that students gain robust conceptual understanding of classroom content when their lessons are supported by visualization tools (Stieff et al., 2005). Positive effects of visualizations use have been noted in chemistry, biology, and physics. It is at this level that visualization tools have been reported as being among the most important technologies for learning at the high school and undergraduate levels (Stieff et al., 2005). Likewise, college teachers have reported similar benefits from enriching traditional pedagogies with visualizations (Stieff et al., 2005). In fact, CD-ROMS and links to internet websites with visualization tools are licensed with many science textbooks, particularly for undergraduate chemistry (Stieff et al., 2005). However, much of the data available on visualizations focuses on its use at the high school and collegiate levels. A minimal percentage of visualization research that has been published that focuses on the middle school level. Those that exist look at how visualizations effect student learning. A gap in the literature exists which focuses on visualization use by middle school teachers, including their views on visualizations within the classroom. This is important to consider as the teacher is the driving force in the classroom. The teacher's decision to implement a specific teaching tool, such as visualizations, can have a direct impact on student interest and performance in such classrooms.

2.5.4 Research Design

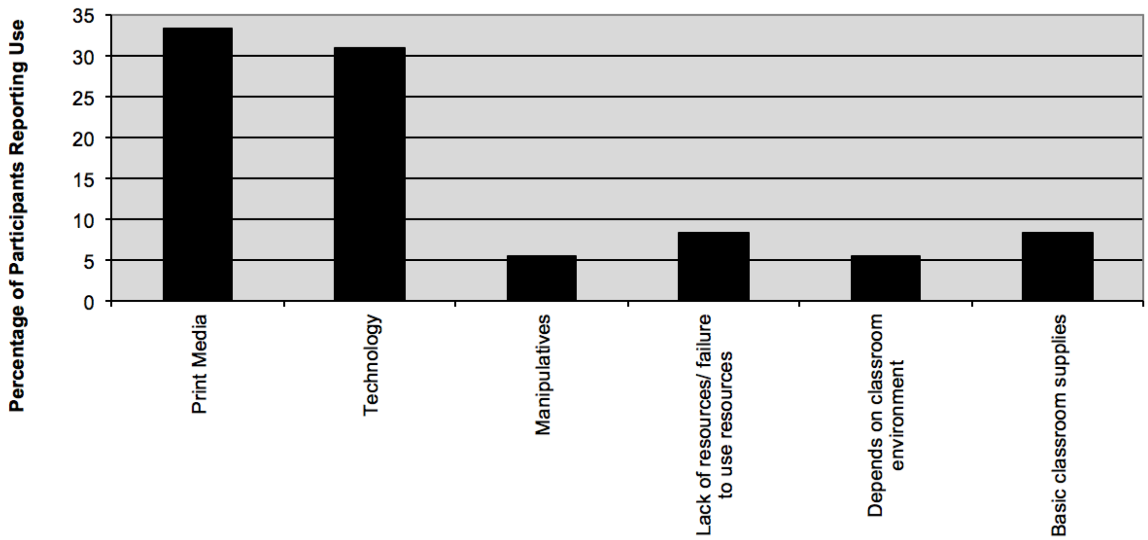
Teachers at a 400 student middle school within a metropolitan city in the Southern United States were asked to participate in the study. Participants included 16 teachers who underwent a 30-45 minute semi-structured interview regarding their views, use, and application of visualizations within the classroom. Data from the interviews were qualitatively analyzed and deductively coded to determine the reoccurring themes that emerged from teachers' experiences and uses of visualizations.

2.5.5 Findings

The study consisted of 16 participants who taught at the middle school level (grades six through eight). Their teaching experiences ranged from two to fourteen years. The participants represented each of the core subject areas of middle school (math, science, social studies, and reading/language arts) and the electives offered at the location (art, band, choral music, physical education, Spanish, and computer technology). Collectively, the participants had a diverse range of teaching experiences that represented all K-12 core content areas, adult reading classes, biblical studies, computer technology, and zoology.

Data indicated that teachers' views and uses of visualizations in the classroom varied depending on several factors. When asked about the frequency of visualization use in class, the responses ranged from not at all to daily incorporation into instruction. The instructional resources most frequently reported by teachers were print media (textbooks, workbooks, and magazines) at 33%, followed by technology (31%) which, for this study, included PowerPoints, DVDs, internet websites, and interactive computer learning software (See Figure 2.3). Of the participants interviewed, 8.3% of the responses indicated a lack of instructional resources or a failure to use them. Some responses (5.6%) indicated that the resources they used depended on the classroom environment which changed year to year and even among classes within a given day. Other responses, (8.3%) indicated that they only used basic classroom supplies such as white board, dry erase markers, color paper, pens, and markers.

Figure 2.3
Instructional Resources Reported by Teachers



Note: During their interview, participants were questioned about the types of instructional resources used to plan lessons. Responses were tallied and graphed.

The percentage of visualization-based resources used by teachers in comparison to other types of resources were 22.9% (Table 2.1). Over eleven percent (11.4) of the responses represented instructional resources that were not visual. Majority of the resources cited were neutral meaning the resource could be visual depending on how it was used. Interviews with teachers indicated they believed that classroom engagement that integrated visual and tactile components helped students learn best. This was evident in 71.4% of the responses that were given under the Ways Students Learn Best category of Table 2.1. "Most kids are visual-picture learners so they must see it and/or touch it," revealed Ms. Johnson, an eighth grade Computer Technology teacher who also assisted in mathematics remediation. This viewpoint was resounded throughout the interviews with majority of the teachers sharing the view that hands-on activities and being able to see and/or manipulate learning components were effective methods. Even though teachers shared this belief, only 33.3% of the ways teachers allowed students to show their understanding of content in class involved a visualization-based component.

Table 2.1
Comparisons of Teachers' Resources and Views About Teaching and Learning

	Includes visuals	Does not include visuals	Neutral
Type of Resources Used by Teachers	22.9	11.4	65.7
Ways that Teachers Believe Students Learn Best	71.4	21.4	7.2
Ways that Teachers Allowed Students to Show Understanding of Content	33.3	21.4	45.3

Note. Neutral includes resources, strategies, and/or activities that could be categorized being visualization-based or not, depending on how they were used (e.g. textbook, which is majority text but includes graphs and other visuals.)

The main uses for visualizations, as reported by teachers during interviews, are shown in Table 2.2.

Table 2.2
Ways in Which Visualizations Were Used in the Classroom

Classroom Use	Examples Given by Teachers
Organization of data	Graphic organizers
A visual depiction of common knowledge in which no new knowledge was created	Create an example of the new nutrition food plate (formerly known as the food pyramid)
A visual depiction of information in which trends were identified	Graphs, equations on the number line, Punnett Squares, interpreting weather maps
Alternative ways to communicate/share learned knowledge	Create a comic strip, create pictures of vocabulary words, create map to show understanding of parallel and perpendicular lines

Note. The table listed ways in which visualizations were used in the classroom, as reported by the participants. Examples for those uses are also provided in the table.

Five themes emerged as factors that influenced the use of visualizations in the classroom and are shown below.

- Student prior knowledge and degree of understanding of the material
- Student behavior
- Time (either for students to create visualizations in class or for teachers to plan the integration of visualizations into the lesson)
- Teacher and/or student comfort level with visualizations
- Amount of control the teacher felt he/she had over what was taught

Visualizations were used when students lacked the knowledge needed to help them visualize complex processes or steps in a process. A fourteen year veteran teacher indicated, “When I teach students about a new concept or a new way of doing something, I show them the process.” A second year art teacher indicated that the use of visualizations helped prevent student and teacher frustration during the learning process, “I walk them through every step on the board so that there’s no way they can possibly make a mistake.” Visualizations were also used as a reference when teachers felt students knew the content but needed a quick review. “Sometimes, I feel the class already understand the idea…so sometimes I’ll just briefly refer to it,” was how Mrs. Hernandez, the Spanish teacher justified it.

Some teachers attributed visualizations as being a distraction in the classroom. At times, these distractions were planned by the teacher. At other times they were unwanted occurrences. Several teachers indicated that visualizations were used in the classroom as a “planned” distraction to help keep students alert in order to increase retention of content.

> "Sometimes during the presentation of a lesson, just to break up the monotony of what the lesson could be about…if it's cute and funny or whatever- it might be a cartoon, it may be a stick man that's jumping up…that kind of style is going to make them remember."

Other teachers indicated that the integration of visualizations in the classroom created a dynamic that the students were unfamiliar with which led to behavior problems (unplanned distractions).

> "Those are some negative dynamics that have caused me to not be able to even think about doing those kinds of [visualizations] with them."

Other influencing factors included being cognizant of instructional time, where many teachers opted for activities that allowed them to do more within the allotted instructional time. There was a direct correlation to comfort level and the openness of teachers to integrate visualizations into the learning environment. When the computer technology teacher was asked about the degree of ease in planning visualizations in the classroom, she replied, "I think it's probably easy for me because that's how I do it anyway. I can't imagine having a lesson without it because they are not going to understand so that'll take more time and I'll have to do it over. It's just easier to do it right the first time." This implies that "doing it right the first time" means integrating visuals which, in her opinion, helps students better understand the lesson and saves time. A science instructor, who primarily used lecture-based instruction possessed a different view of visualizations. He admitted to not using visualizations in class because "I think that 90% of classrooms are lecture-based because it's easier. I can hurry…I can discuss it, we talk about it, then we can move on." When asked why he used visualizations so sparing he replied, “I’m not comfortable with it. And I think the things that we’re not comfortable with, we shy away from…because it’s something different and I equate different sometimes with being cumbersome.”

Teachers who taught subjects with a prescribed program such as Reading! or Reading 180 also indicated that they used images sparingly because they felt they didn’t have control or they did not desire to deviate from the layout of the program.

In classrooms where teachers allowed students to generate their own visualizations, teachers listed possible student benefits. Those benefits were broken down into four categories.

- Better/alternative way students could communicate mastery of the content
- Activated a different part of the brain
- Allowed for student creativity
- Helped with retention of content and concepts

For student generated visualizations, teachers chose either to grade student visualizations using a rubric or to offer no grade for the product.

2.5.6 Conclusions

Teachers have varied experiences with visualizations within the middle school classroom. When teachers allowed students to create visualizations in the classroom, the most common uses were to convey a message or concept. The most common types of visualizations used were through the use of graphs, maps, and visual stories. This fell in line with some of the ways visualizations are used in the professional community (Rundgren & Tibell, 2010). However, in the professional community, visualizations are commonly used to bring simplicity to more complex phenomena, none of which were the uses indicated by the teachers (Rybarczyk, 2011). Although teachers indicated that their students were highly visual, only one participant had attended or been offered any classes that focused on visualization use as an instructional tool in the classroom. The offered professional development opportunity was afforded to a reading teacher in which the visualizations were mostly used as tools to organize students' reading, comprehension, and writing.

For teachers that used visualizations as a component of their instructional methods, they considered it easy to plan for while those teachers who failed to use visualizations found it more difficult to use. Overall, they welcomed visualizations as a learning and instructional tool. Teachers indicated that their students were highly visual learners who can be served best by visual and kinesthetic instructional methods, however, formal education provided to teachers regarding their use in the classroom is slim.

2.5.7 Implications and General Interest

Data indicated that teachers could benefit from professional development opportunities that help align the benefits of visualizations with their instructional goals within the classroom. The data also indicated that while teachers held visualizations in high regards according to their ability to help students learn, barely one third of student activities were comprised of such learning components. Because of the low amount of visualization-based activities developed for students, more attention should be devoted to this phenomenon at the middle school level. Not only could doing so increase student academic performance but it could also help deter behavior problems when they are used appropriately. Doing so would increase teacher comfort level with using visualizations.

Additional research is needed to determine ways in which professional development opportunities could best be designed to fit the needs of teachers.

CHAPTER III – RESEARCH METHODS

3.1 Introduction

This chapter presents the research design, the role of the researcher, criteria for selection of participants, methods of data collection, and data analysis that was used in this study. This study was qualitative and used the grounded theory epistemology for the purpose of developing a substantive theory from themes and categories which emerged from the data.

This study sought to understand the barriers and facilitators which shaped teachers' experiences as it related to visualization-based instruction and the processes they employed in planning to use and implementing such instruction. A grounded theory approach was used to understand and predict this phenomenon. Grounded theory guided the data collection and analysis through the use of various types of data: classroom observations, semi-structured interviews, and teaching artifacts.

3.2 Research Questions

The following question guided this study: What are the barriers and facilitators that guide visualization-based instruction by middle school teachers in science classrooms?

Subquestions for this study were:

1. How do middle school science teachers' view visualizations as an instructional tool compared to other instructional tools?
2. How are middle school science teachers planning for and using visualizations in the classroom?

3. What types of training have middle school science teachers obtained on the use of visualizations as an instructional tool?
4. What factors influence the use of visualizations in the middle school science classroom?

3.3 The Role of the Researcher

This study was qualitative in nature. The researcher served as the primary instrument for data collection and analysis. Data was collected through constant classroom observations, interviews, and collection of artifacts. The data, when necessary, was transcribed. All data was analyzed using the three step coding process associated with the grounded theory methodology (Strauss & Corbin, 1967). The emerging themes and categories were tested and finalized.

In qualitative research, the researcher plays an important role in that the researcher is directly involved in the data collection process and typically has high levels of interactions with the participants (Chazman, 2006). Prior to the onset of this study, the researcher developed a positive professional working relationship with the participants. The researcher served as a science instructional leader where she routinely engaged in discourse with science teachers regarding teaching strategies, challenges in the classroom, and student learning and performance. This role, held by the researcher prior to the start of the data collection process, helped build a system of trust among the researcher and the participants by which participants could free to honestly share information throughout the data collection process.

3.4 Research Design

This research was a qualitative study that utilized the grounded theory tradition. This particular theory was chosen due to the degree of insufficiency in other theories in guiding one toward understanding the selected phenomenon. These theories were inadequate in providing a solid structure from which to develop a study to answer the research questions. For example, methodologies associated with case studies aim to guide the researcher in understanding a refined group's dynamics with a "specific, unique, bounded system" without the intent to apply those understandings to future and/or similar situations (Patton, 2002). Phenomenology is an approach to understand the experiences of a group of people in relation to a common event or activity. It is also not implemented with the intent of applying those understandings to the creation of generalizations about a population (Patton, 2002). While this study was focused on understanding the experiences of middle school teachers as it related to visualization-based instruction, the context of this study was not limited to their experiences alone. Grounded theory, therefore, is a more appropriate framework for the study allowing a multitude of aspects to be analyzed and generalized into theory.

3.5 Grounded Theory

Grounded theory is an epistemological framework with a specific methodology embedded within. The methodology allows theory development though the work of observations, interactions, and materials gathered about a topic or setting. Empirical events and experiences are coupled with hunches and potential analytical ideas (Charmaz, 2006). Each step is guided by the reading and interpretation of the data (Charmaz, 2006).

This process allows the researcher to build a theory in abstraction from the data and to collect additional empirical data to test and refine the theory (Charmaz, 2006).

Grounded theory coding is based on several types of coding (Charmaz, 2006). During initial coding, the data is analyzed in fragments (Charmaz, 2006). Through focused coding, the most useful initial codes are tested against the data. Open coding involves the identification and grouping of concepts to form categories. In doing so, each event and situation related to the aim of the study is labeled with a code. These codes are then compared and those with a similar content are grouped into categories that become representative of a higher level of abstraction (Strauss & Corbin).

In the axial coding, the categories are developed by searching for a relationship between and within them by constantly going back and forth between the categories and the data. This process is used to relate categories to subcategories and outlines the specific properties and dimensions of a category (Charmaz, 2006). This process is used to sort, synthesize, and organize large amounts of data and reassemble then in a new way after open coding (Charmaz, 2006). It links categories with subcategories and show how they are connected and is a strategy used to bring the data back together again in a coherent whole (Charmaz, 2006).

In the selective coding, theoretical selection is utilized to compare the different categories. These categories are tested against existing and/or new data to determine how the descriptions of the phenomenon belonging to each category were related and how they could be explained. During the analysis process, memos are continuously written to support the development of the model.

Memo writing provides ways to compare the data, to explore ideas about the codes, and to guide the further data collection process (Charmaz, 2006). Derived from the comparisons of codes and other ideas regarding the data, memo writing forms a pivotal point between categories and theory development.

Throughout the process, the researcher focuses on collecting "rich" data in which the information is detailed, focused, and tells the full story. It may focus on participants' actions, views, feelings, intentions, the contexts, and structure of their lives (Charmaz, 2006). The data process is also considered to be "thick" because of its degree of details and extensiveness (Charmaz, 2006).

Theoretical sampling involves the specific and strategic reentry into the field to collect data specifically with the developed categories in mind (Charmaz, 2006). Theoretical sampling continues until no new categorical properties emerge (Charmaz, 2006). Therefore, the categories are saturated with data. When conducting theoretical sampling, the focus is on processes- participants' actions, experiences, events, and issues- not on the individuals themselves (Charmaz, 2006). This helps in the formation of an abstract theory.

Grounded theory uses constant comparative methods to help illicit the developing theory. Initially individual codes are compared against each other. At each step, the product is compared against the data to ensure it is representative of the data. The categories are compared against the data and the codes from which they came until a sustainable theory has been derived. Strauss and Corbin defined a theory as 'a set of well-developed concepts related through statements of relationship, which together constitute an integrated framework that can be used to explain or predict phenomena' (Charmaz, 2006). In their views, a theory is much more abstract and explanative that just a description of a phenomena. In the end, the theory is compared to the data from which it came and the associated literature.

3.6 Selection of Participants

Prior to the onset of the research, consent to conduct the research was granted through the Institutional Review Board at The University of Southern Mississippi. Permission to conduct the study was also granted by Jackson Public School District and the principal at Kirksey Middle School. Once permission was given to conduct the study, participants were informed of the study and given an opportunity to give their informed consent.

The participants of this study were middle school science teachers within the Jackson Public School District at Kirksey Middle School. Participants included one sixth, one seventh and one eighth grade science teacher. The small sample size does not hinder the grounded theory process because of its focus on developing conceptual categories (Charmaz, 2006). The school district in which the study took place has 12 middle schools. This specific site was selected because it was a recent addition to the school district. Being three years old, the school was designed to cater to mathematics and science education and provided various options for teachers desiring to integrate technology into their classrooms. Therefore, access to technology and visualizations would not be seen as a limiting factor in teacher’s ability to design and implement visualization-based instruction, if desired.

3.7 Data Collection

The sources of data collection included classroom observations, open-ended semi structured interviews, card sorting tasks, a learning style inventory, and artifacts associated with the planning and teaching of instruction. Such artifacts included lesson plans, photographs of information placed on classroom whiteboards, pictures of manipulatives, grading rubrics, and copies of tangible and computerized instructional aids. Computerized instructional aids included websites, PowerPoints, videos, simulations, computer-based programs, and programs used for tutorials, remediations, and interventions.

Data was triangulated with its collection from multiple sources concerning the same area of interest. For example, to understand ways in which the teacher felt students learned best, data was collected from interview questions regarding the topic, analysis of the lesson plans in which the teacher designed ways for students to show their understanding of a concept, and through classroom observation.

The data was collected continuously with the process of analysis, in alignment with the grounded theory tradition. The various sources of data were collected and analyzed until no new categories could be established (Strauss & Corbin, 1998).

3.7.1 Participant Interviews

Interviews were conducted as a method of data collection and they have been noted to fit extremely well with the grounded theory methodology (Charmaz, 2006). Interviews were conducted at the onset of the study, after classroom observations, and as needed to gather additional information regarding the thought process the teacher used in deciding to use visualizations and the manner in which visualizations were used in the classroom.

Interviews for clarity were longer used after no new data emerged. This included interviews in regard to collected artifacts and to test potential theories. Interviews requiring clarify of data took 10-15 minutes. Initial and final interviews used to gain insight into the participant's beliefs of visualization-based instruction, beliefs on other popular pedagogies, and their formal training took approximately 45 minutes. All interviews were semi-structured, audio recorded, and transcribed.

Several rounds of interviews were conducted with participants to gather a deeper understanding of the teacher's selection process for the use of specific instructional aids, the teacher's degree of comfort with using the aids, the level of effectiveness in achieving the desired results, and the process and ease with planning for the use of the instructional aid. The interviews were used to gather information regarding modifications in the instructional based on what the teacher planned to do according to the lesson plan and what was actually implemented in the classroom. Final interviews with participants disclosed participants' beliefs in effectiveness of various instructional strategies and instructional aids and their formal preparation for visualization-based instructional through undergraduate, graduate, or professional development courses.

Data collection and analysis was done simultaneously. The interview transcripts were read several times in order to become familiar with the content and analyzed via open, axial and selective coding as outlined by Strauss & Corbin (1998).

3.7.2 Classroom Observations

Classroom observations was conducted daily throughout the duration of the research project. The duration of classroom observations was for the entire class period which consisted of 52 minutes. During classroom observations, data was collected on the types of visualizations used during instructional time, the intended purpose for the visualizations, the manner in which the tool was used, and the apparent comfort level in which the teacher used the visualization. Classroom observations were also used to determine if visualization-based instruction was carried out as intended during the planning of the lesson and factors within the classroom which led to the use of visualizations which were not initially planned. Classroom observations continued until no new data emerged which allowed new categories and themes to emerge and the proposed theory was been validated.

3.7.3 Card Sorting Task

The card sorting task was outlined by (Friedrichsen & Dana, 2003). The card sorting task was used to allow the participant to categorize various instructional strategies according to their opinions on degree of effectiveness in helping students understand science content. The information was used to compare the participants' beliefs with how they planned for and implemented instruction within the classroom.

3.7.4 Lesson Plans

At the research site, teachers were required to submit weekly lesson plans in the Madeline Hunter Format which outlined curriculum competences and objectives to be taught, instructional goals for the week, a detailed description of the activities the teacher designed, and ways in which the teacher will allow students to show mastery of the objective. Lesson plans were used to analyze the types of visualizations the teacher planned to use, the way in which he or she planned to use the tool, and specific objectives in which visualizations are commonly associated with.

3.7.5 Additional Instructional Artifacts

Any instructional aids used by the teacher which had a visualization-based component was also analyzed for the study. This included information placed on the boards, handouts, manipulatives (including hands-on activities and labs), computer-derived information, and computer generated information. The use of these aids, by the teacher, were analyzed in the same manner as the other instructional strategies- the purpose in which it was used, how it was used, and the apparent degree of comfort in which the teacher used the aid.

3.7.6 Field Notes

Field notes were used throughout the data collection process to help facilitate the interpretation and analysis of the data. Field notes included self-notes to the researcher, reflection of interviews and classroom observations, thoughts stemming from the interviews, and analysis of data. These notes were used to help guide the development of a substantive theory.

3.7.7 Memo Writing

Memos were used in coding process to guide the thought process of the researcher in raising new questions which would further guide the data collection process in the field, and when necessary, the reanalysis of the information that had already been collected. The use of memos guided the inductive analysis of the data. Once categorizing of data began, deductive analysis of the data was used to verify categorizes that had been established.

3.7.8 Data Analysis and Interpretation

Data collected during this study was analyzed in a manner consistent with the grounded theory tradition. This tradition calls for the simultaneous data collection and analysis. The data was coded to allow categories and themes to emerge. Data collection, analysis, and interpretation continued until a point of theoretical saturation was reached (Chazman, 2006). Potential theories will be tested against the data and refined until a substantive theory was developed.

3.7.9 Statement of Trustworthiness

During the development, implementation, and analysis of this study, strategic steps were taken to ensure the trustworthiness of the results and conclusions. This were done by focusing on four major areas as identified by Lincoln and Guba (1985). These four areas are credibility, transferability, dependability, and confirmability.

Prolonged engagement within the research environment and developing a rapport with the educators provided a foundation that developed credibility. Observation guidelines, field notes, and the triangulation of multiple data sources (pre/post participant interviews, classroom observations, and analysis of lesson plans) extended the credibility of the study. Credibility was also established by the richness of the data collected in that its findings may be applicable to other "realities" within the same or similar context and demographics. Peer debriefing was used to help ensure the researcher continued to approach the study and analyze the data objectively and with empathic neutrality. Peer debriefing was also used as triangulation of analysis.

Senior researchers served as the external auditors who ensured that the research design, collection process, and analysis was accurate and the conclusions were based on the data. An audit trail was kept which further enhanced the dependability and confirmability of the research findings.

A dense description of the project, which detailed the environment from which the data was drawn helped achieve external validity through transferability. Transferability of the data was enhanced not only by the development of a substantive framework but also by the rich descriptions of the context, participants' responses, actions, and interactions.

3.7.10 Summary

This chapter described the research project in terms of the research questions, the research design, its participants, the process of data collection and analysis, along with evidence for reliability and validity. Grounded theory tradition was used which is inclusive of a specific and detailed manner of collecting and analyzing data. This specific methodology was used to better understanding the barriers and facilitators that existed as it related to teachers' experiences with visualization-based instruction for middle school students within the science classroom.

This chapter also provided a thorough description of the process associated with grounded theory as it relates to qualitative research. Data collection occurred over a period of three months. The data from the study was used for analysis such that a substantive model could be developed based on theory. Findings, conclusions, and recommendation will be presented in the subsequent chapters.

CHAPTER IV – FINDINGS

4.1 Introduction

The purpose of this research was to investigate the barriers and facilitators of visualization-based instruction by middle school science teachers' in science classrooms. The understanding of this phenomenon aided in the development of a theoretical framework which addressed implications at the middle school level for science instruction. Prior to this qualitative research study, a pilot study was conducted using middle school teachers of various content areas to gain a context of teachers' experience with visualizations at the middle school level. For this study, three science (a sixth grade, seventh grade, and eight grade) teachers were studied to gain a better understanding of the role visualizations play in science classrooms. Participants provided data through in-depth semi-structured interviews, classroom observations, lesson plans submitted for analysis, completion of two card sorting tasks, and a learning style inventory.

All collected data was analyzed using grounded theory methodology and conceptual framework to determine the barriers and facilitators that guided visualization-based instruction. The subquestions were:

1. How do middle school science teachers view visualizations as an instructional tool compared to other instructional tools;
2. How are middle school science teachers planning for and using visualizations in the classroom;
3. What types of training have middle school science teachers received on the use of visualizations as an instructional tool; and

4. What factors influence the use of visualizations in the middle school science classroom.

This chapter begins with a look at each of the research questions and an analysis of the data collected from the teachers collectively as it relates to each question. The chapter ends with a miniature case study in which each science teacher was studied individually. The strengths and weaknesses of the teachers' science content, pedagogy, and general knowledge and use of visualizations were identified. This provided understanding on how visualization use differed across science classrooms. The data was then analyzed as a whole and used to develop the forthcoming framework.

4.2 Middle School Science Teachers' Views on Visualizations

The first subquestion was: How do middle school science teachers' view visualizations as an instructional tool compared to other instructional methods? Several interview questions were formulated to collect of the needed information.

During the initial interview, teachers were questioned about possible benefits of using visualization-based instruction in the classroom. Most teachers attributed visualizations with providing a better or alternative way for students to take in new information. They listed visualizations with assisting students in making connections between existing information. Visualizations were attributed with providing new pathways for students to communicate their understanding of science content. Teachers linked the use of visualizations with activating a different part of the brain. Deeper understanding of concepts, increased retention of topics covered in class, and greater student creativity were also seen as benefits.

Table 4.1

Teachers' Views, Resources, and Methods Based on the Presence of Visualizations

	Includes visuals	Does not include visuals	Neutral
Ways that Teachers Believe Students Learn Best	70.0	20.0	10.0
Type of Instructional Resources Used by Teachers	23.1	15.4	61.5
Assessment Methods Used by Teachers	33.3	50.0	16.7

Note. Teachers' perceptions of how students learned best compared to resources and assessment methods used in science classrooms. Neutral includes resources, strategies, and/or activities that could be categorized as being visualization-based or not, depending on how they were used (e.g. textbook, which is majority text but includes graphs and other visuals.

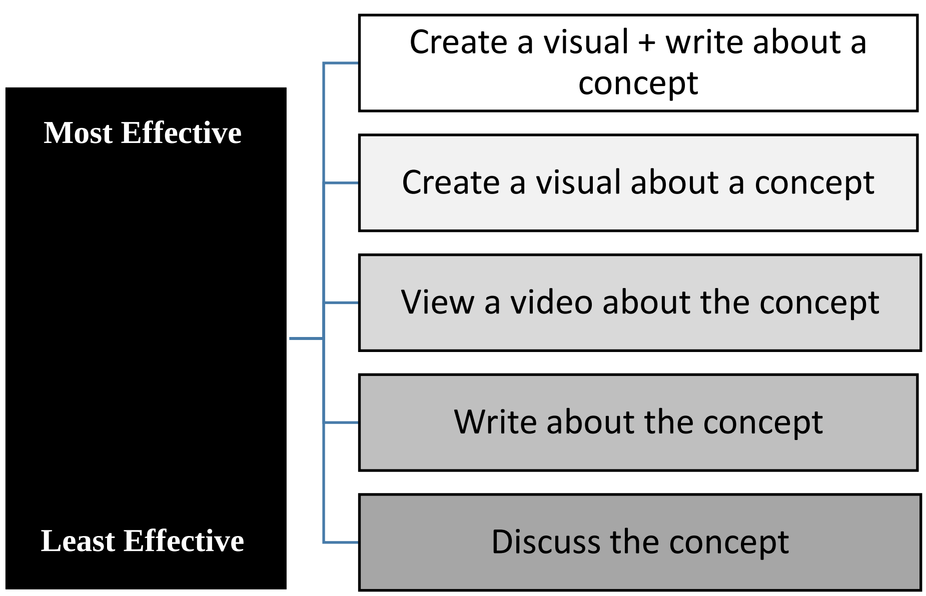
During the initial interview, teachers were asked to list the types of activities they felt were most beneficial to help students learn science content. During the same interview, participants were asked about the types of resources they used when they planned for and delivered instruction as well as various methods used to assess student knowledge. Their responses were collected and percentages were determined based on whether the response included visuals or could be labeled as neutral. Responses are shown in Table 4.1. Responses such as the use of instructional videos or having students draw the steps in the water cycle, which used a high degree of visuals, were categorized as a visual method. Examples of nonvisual methods were those that primarily used text such as summary paragraphs, essays, and lectures. Responses were categorized as neutral if the manner in which they were used determined whether the method was visual or nonvisual. Examples of neutral activities included the use of PowerPoint which could be used to either illustrate visual concepts or provide written notes in a simplified manner.

Seventy percent (70.0%) of teachers' responses indicated that teachers believed visualization-based activities benefitted students during the learning process. Of the recorded responses, 20.0% of the methods teachers cited as helping students learn best were nonvisual. When questioned about the type of resources used during the planning of or implementation of instruction, 61.5% of the responses given by participants were neutral with 23.1% of the cited resources being visualization-based and 15.4% of cited responses being categorized as non-visual. Only 33.3% of responses indicated students were visually assessed, with majority of assessment methods being nonvisual. More than a fourth of the responses, 28.5%, indicated assessment methods were neutral.

4.3 Methods in Which Teachers Feel Students Learn Best

Teachers allowed students to create visuals such as posters, comic strips, animated cartoons, graphics, and graphic organizers to show understanding of concepts. Students drew the water cycle, created lab safety posters, and cell models. Activities such as answering questions, homework, worksheets, and creative writing assignments ranked high among teachers' responses.

Figure 4.1
Science Teachers' Rating of Instructional Strategies



Note. Science teachers' rating of instructional strategies based on how effective they believed they were in helping students understand science concepts.

Teachers were asked to complete a card sorting task in which they rated five instructional strategies based on how effective the strategies were in allowing students to show their understanding of a taught concept (See Figure 4.1). The five strategies were:

- write about the concept;
- discuss the concept;
- view a video about the concept;
- create a visual about the concept; and
- create a visual + write about the concept.

For the science teachers, having students create a visual + write about the concept, and, having students create a visual about the concepts were the the top two responses. Writing about a concept and discussing the concept were listed as the least effective among the five strategies.

As teachers completed the card sorting task, they were asked to 'think aloud' and share their rationale behind the order of the cards they selected. Responses indicated that teachers shared similar views as it related to why certain strategies were more effective than others. Teachers were more apt to select Create a Visual + Write about the Concept card because they felt it met both the teacher's and students' needs. By combining the two (write about the concept and create a visual), the teachers felt they could clearly see where students' misconceptions existed. Also, teachers felt students were more engaged in assignments when visual components are added.

Create a Visual card also rankly highly because teachers felt that if students could create a visual from memory that explained a concept, then the student showed mastery of the concept. The teachers believed the places where student struggled when creating the visual would directly correlate with the areas of the concepts where the student lacked knowledge.

Discussing the concept was not viewed as effective as other the methods. Teachers felt it provided too many opportunities to get off topic. This sentiment was expressed for small group and peer-to-peer discussions. During discussions, only one person talked while all others listened. This allowed a significant amount of class time to elapse while many student were not actively engaged and contributing to the discussion. While veteran teachers may be aware that student attempts to avoid class discussions could indicate the student may be uncomfortable with the material, this factor may be overlooked by new teachers. It can also be overlooked by teachers with large class sizes in which it is more difficult to quickly identify unengaged students. There is also a decreased ability for each student in a large class to contribute meaningfully to the conversation within a given amount of time. Also, one teacher indicated that at the middle school level, students were familiar with many concepts but lacked the terminology to discuss it in class. One example given by a teacher was a class discussion about an oscillating fan in which several students had no idea what was meant by "oscillating." But, once the teacher thoroughly described the object, students realized they knew what it was, its purpose, and how it worked.

This same issue arose when students were given writing prompts. Teachers noticed that majority of their students were not skilled enough to keep their writing on topic. Also, students' writing often was not adequate enough to satisfy the expectations of the writing prompt. Students would only scratch the surface of the topic, providing sentences that gave basic details without inciting any thought. When extended time was given for writing assignments, such as for homework, students often plagiarized information from websites and books. This decreased the teacher's ability to gauge progresses in students' understandings. Those teachers who ranked the writing card higher did not have students that showed these same deficits in writing. These teachers believed that a student's ability to thoroughly write about a topic indicated their degree of understanding.

4.4 Planning for and Using Visualizations Within the Classroom

The next research question was: How are middle school teachers planning for and using visualizations in the classroom?

Table 4.2
Level of Difficulty in Planning Visualization-Based Instruction

Descriptor	Percentage of Total Responses
Depends on the visual being used	28.6
It is equally easy or easier	21.4
Depends on available time	14.2
It is equally difficult or more difficult	7.1
Depends on how well students understand the information	7.1

Note. Level of difficulty in planning visualization-based instruction when compared to other instructional methods, as reported by teachers. Participant responses were calculated to determine percentage of total responses.

Participants were questioned regarding the degree of difficulty they experienced when planning visualization-based lessons as compared to lessons that used other instructional formats (See Table 4.2). Nearly thirty percent (28.6%) of participants' responses indicated that the degree of difficulty varied depending on the type of visualization they used and the goal of the lesson. Over twenty percent (21.4%) of the participants' responses indicated that developing visualization-based lessons were just as easy as other types of instructional strategies. This response was given by teachers who were comfortable using technology. These teachers frequently allowed students to create visual products or the teachers often used visual products to engage students. Time was a factor for 14.2% of responses. These individuals indicated that integrating visualizations into their lessons was more time consuming. For example, developing a PowerPoint was considered time consuming because each slide played a role in the lesson's ability to meet the specific learning goals. While it was easy and less time consuming to find a PowerPoint on the internet to cover a specific topic, it was not always the best fit for the students or the learning goal. Also, showing a video was listed as being extremely easy to plan for but teachers mentioned that this was not always the best method to keep students engaged. Of the responses given, 7.1% indicated that integrating visualizations into their lessons were just as difficult as other instructional methods or more difficult. The level of difficulty was found to be related to an inability to plan lessons with ease (regardless of the instructional method used), the inability to use technology with comfort, or inability of the teacher to engage students via different modalities. Because visualizations are often tailored for specific topics and concepts, finding a ready-made visualization to use created an additional layer of stress to the lesson planning process for some teachers. In these instances, using visualizations was not considered.

Some teachers indicated that when students understood the concept, integrating visualizations as a review was easy. Doing so allowed the teacher to quickly assess students' understanding and move on to the next topic. In other instances, visualizations were easy to use when students lacked a complete understanding of the topic. In these cases, visualizations provided a method to introduce information to students.

During the interview, teachers shared ways they allowed students to show their understanding of concepts and to measure mastery. Oral discourse was the most popular method in which teachers analyzed students' understanding. This occurred through oral questioning, whole class discussions, discussions among cooperative learning groups, and the teacher and class working collectively through an activity.

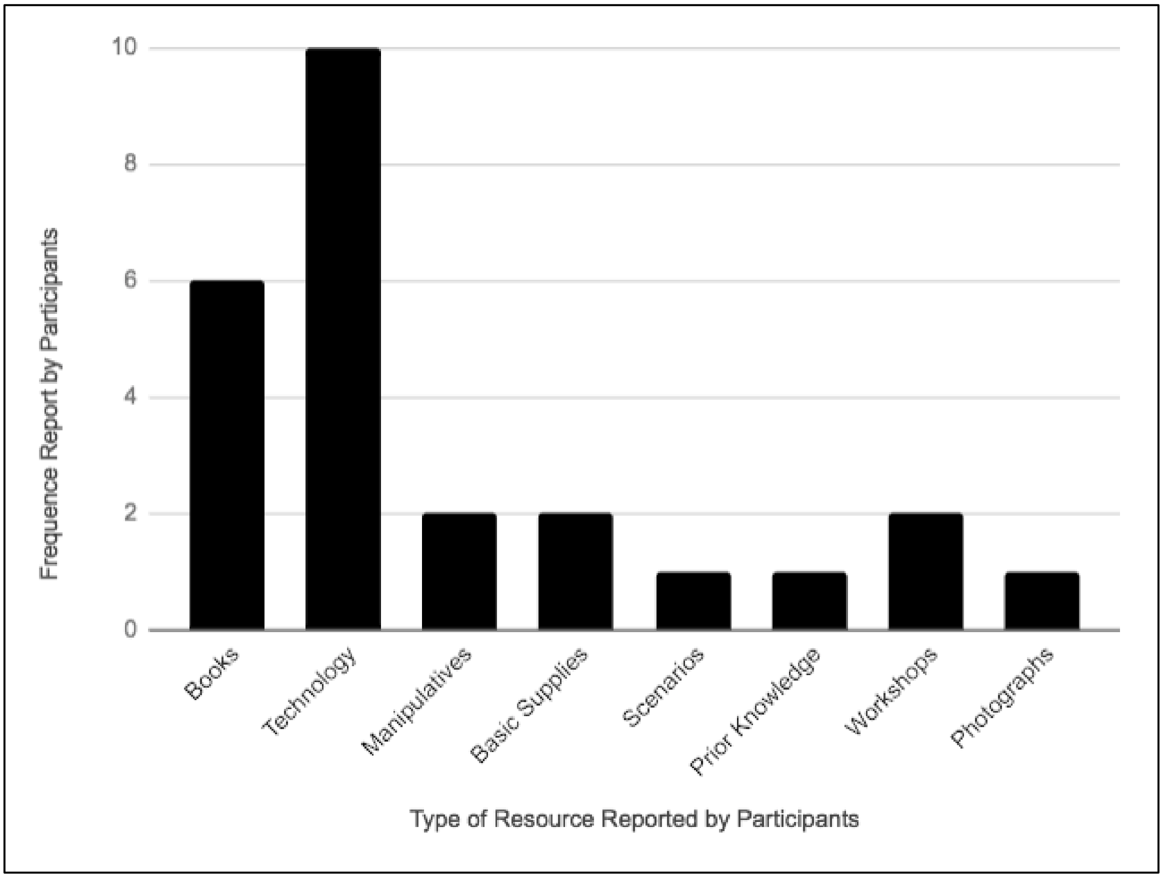
Teachers frequently allowed students to show mastery of newly learned material by utilizing the information in a new way such as student-created labs, kinesthetic activities, and scenarios.

Additionally, formative and summative assignments were frequently reported as methods used to allow to show their understanding of concepts. This included quizzes and tests. In some instances, it included labs and research-based reports.

To develop a greater understanding of the ways teachers planned for and used visualizations, several data sources were used. Lesson plans submitted by participants were analyzed. Each of the lesson objectives were evaluated for associations with visualization-based activities, the Depth of Knowledge (DOK) Level of the activity was determined, and the purpose of the activity was identified. Classroom observations and interview material were also used to gain a clear understanding of how visualizations were used when in the classroom.

Teachers were asked about the resources they used when planning lessons. The frequency of their responses is shown in Figure 4.2. Among science teachers, technology was the most cited resource used. This included educational videos, iTunes

Figure 4.2
Instructional Resources Reported by Participants



Note: During their interview, participants were questioned about the types of instructional resources used to plan lessons. Responses were tallied and graphed.

University, websites, powerpoints, SmartBoards and iPad apps. Books were also used with high frequency and included the textbook and instructional resources provided by the textbook publisher such as student workbooks and guided notes.

Most of the resources listed by the teachers were used in a manner that allowed students to create physical products. This included manipulatives and other resources that teachers received from attending workshops and conferences. Teachers also listed basic classroom supplies such as construction paper and scissors. One teacher specifically listed still photographs as a resource she frequently used because it allowed her to show students different phenomenon (such as animals interacting with biotic and abiotic factors to teach animal adaptations, cycles in nature, to infer, make observations, and other skills).

Table 4.3
Classroom Uses of Visualizations

Classroom Use	Examples Given by Teachers
Visual organization of data in which no new knowledge was created	• Graphic Organizers • Draw cycles in nature • Label parts of cells • Create a comic book
A visual depiction of information in which trends were identified	• Interpret charts and graphs • Punnett Squares • Interpret weather maps
Transfer/application of knowledge	• Analysis of scenarios • Develop unique species based on environmental conditions given • Analysis photographs

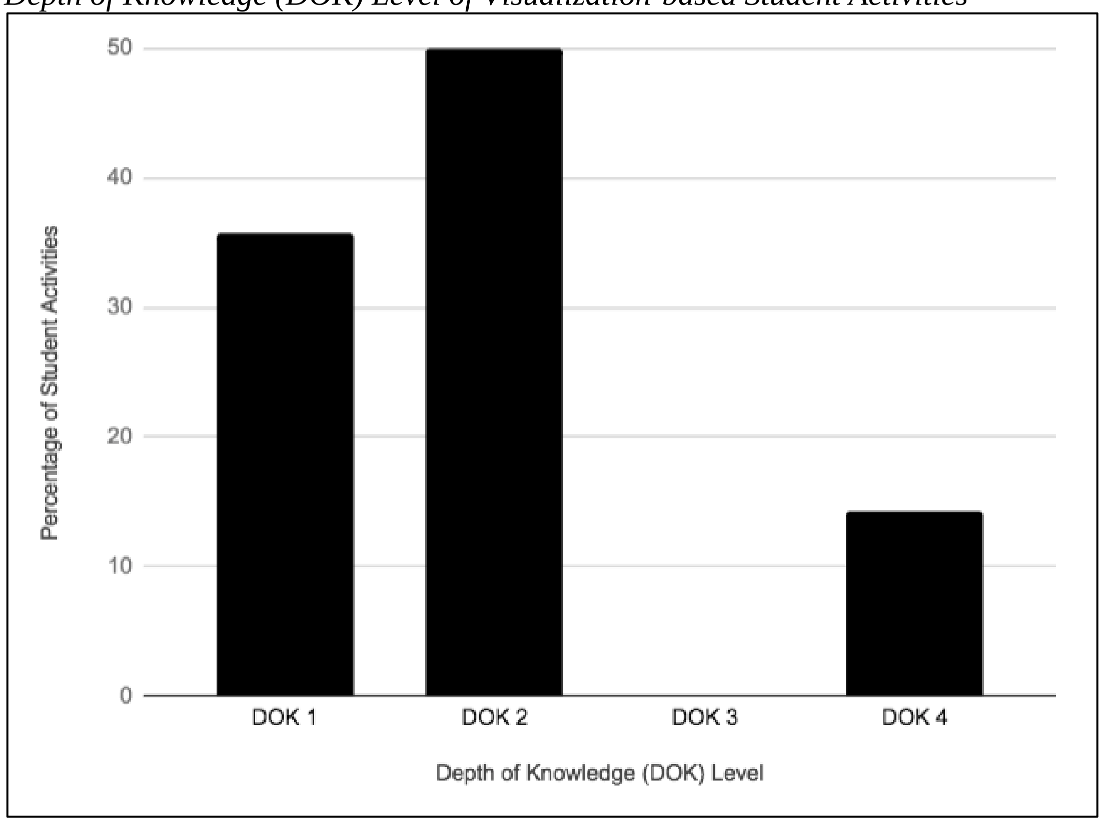
During the interview, teachers were asked to describe ways in which they used visualizations. Their responses and specific examples given aligned with the data collected through classroom observations and analysis of their lesson plans. Their responses were categorized into three groups (See Table 4.3). The first category was visual organization of data in which no new knowledge was created. This included grouping information obtained from lectures, videos, or from the textbook. This was commonly done by using graphic organizers, putting information into tables, or color coding information (e.g. coloring metal elements on the periodic table a specific color). This also included activities such as the creation of foldables (e.g. where each tab of the foldable described a different type of cell).

Using visuals to identify trends was the second category and often used in science classes when students collected or was given data. Examples included interpreting trends and inferring information from graphs, predicting of the genotype and phenotype of organisms of species using Punnett Squares, and predicting upcoming weather events based on a given weather map.

The third category included using visuals to apply newly learned content to novel situations. With these activities, students needed to refer to prior knowledge, new knowledge, and the new situation to develop a visual that met the learning goal. Examples included analyzing and responding to unique scenarios, creating new species based on a set of unique environmental conditions, and analyzing photographs in which the new knowledge must be used to explain the phenomenon.

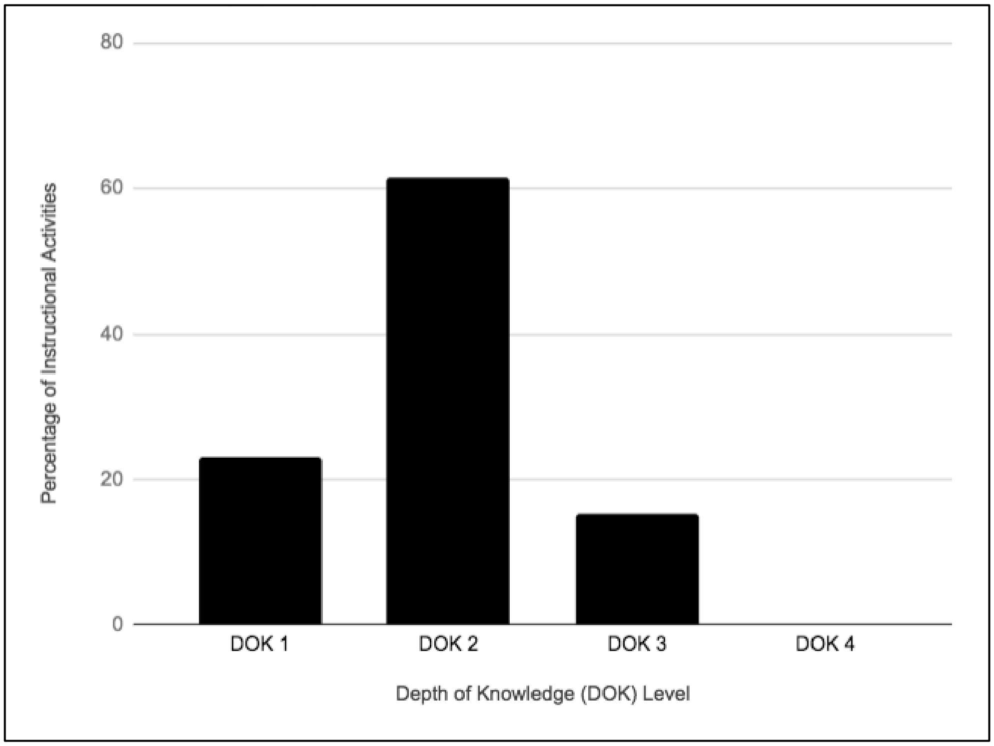
Figure 4.3

Depth of Knowledge (DOK) Level of Visualization-based Student Activities



Depth of Knowledge is a term used in education to indicate the level of cognitive function needed to complete a task. Activities in teachers' lesson plans were analyzed based on their DOK level. Data indicated that majority (50%) of activities in teachers' lesson plans that were designed for students were level DOK 2 (See Figure 4.3). DOK 2 activities that teachers planned included interpreting charts and graphs, reading weather maps, classifying organisms, and using Punnet Squares. This aligned with the types of activities teachers indicated they used when they were interviewed. Over a third of the student activities, 35.7%, were DOK 1. These activities required the lowest amount of cognitive function. Drawing cycles in nature, labeling parts of the cell, and using models were examples of DOK 1 activities noted in lesson plans. None of the activities listed in the science teachers' lesson plans were categorized as DOK 3. Activities such as asking students to draw conclusions or creating unique products would have been categorized as DOK 3. This does not indicate that such activities were not done in class. They were not cited as examples by the participants nor were such activities pre-planned in their lesson plans.

Figure 4.4
Depth of Knowledge (DOK) Level of Visualization-based Teacher Led Instruction



Similar trends were seen in the types of instructional activities that teachers conducted when teaching. Data from lesson plans and classroom observations were analyzed and categorized according to DOK level (See Figure 4.4). Of the teachers' instructional strategies that were analyzed, 23.1% of the activities were DOK 1, 61.5 were DOK 2 and 15.4% of the instructional activities were DOK 3.

Each science teacher had a different method for grading visualization-based activities. The frequency in which activities were graded ranged from not very often to not at all. One teacher indicated that visualization-based activities were either not graded or the grade was based on effort, not accuracy. Another teacher indicated she did not have a grading method. The third teacher indicated that she always used rubrics to grade students' visual products.

4.5 Training on the Use of Visualizations as an Instructional Tool

The third subquestion I investigated was: What types of training have middle school science teachers obtained in the use of visualizations as an instructional tool? Interview responses indicated that teachers received minimal training, if any, on the incorporation of visualizations into lessons. All participants taught a minimum of seven years but none had attended a formal course or workshop on visuals and the role they could play in instruction. Two of the participants attended summer workshops where manipulatives and visuals were incorporated but, they were not the main focus of the workshop.

4.6 Factors Influencing the Use of Visualizations in the Middle School Science Classroom

My final subquestion was: What are factors influencing the use of visualizations in the middle school science classroom? This question focused on classroom and environmental factors that impacted whether visualizations were incorporated into daily lessons. Teachers were asked about the factors that determined their daily instructional activities. The top six responses, in order of frequency were:

1. student knowledge/lack of knowledge;
2. students' individual learning needs;
3. time;
4. curriculum/learning goals;
5. classroom management needs; and
6. the teacher's comfort level with the material.

For most teachers, student knowledge of the topic had the greatest influence over what was done in the classroom. Teachers considered students' prior knowledge along with considerations of how each student learned best. These factors combined to help teachers determine which activities were ideal for the class.

Time played a large role in teachers' decisions to select specific activities. This included the expected time for students to understand the concept and the amount of time left in class when the activity was going to be introduced to students. Teachers did not want to begin an activity if it could not be completed the same day. Teachers indicated that for some activities, students were better served if they were guided through the activity from beginning to end instead of being allowed to complete it for homework. Even though teachers estimated how long it should take students to complete the activities in their lesson plans, unforeseen factors often had an effect on the teacher's ability to implement the activities as planned. This included students taking longer than expected to grasp the concept, time lost to deal with behavior problems, impromptu assemblies, or loss of prep time.

The curriculum issued by the Mississippi Department of Education and refined by the school district was one of the factors cited by teachers. The school district coupled the curriculum with a pacing guide that outlined what topics teachers were expected to cover throughout the school year and the amount of time that should be spent on each topic. This allowed all teachers of the same grade level and subject to cover the same topics around the same time in the school year. The district implemented this design due to its high number of students that transferred to different schools within the district each year.

The curriculum guide also helped teachers stay on target when selecting learning activities.

The behavior of individual students and the behavior dynamics of entire classes played a role in the types of activities that were selected. As the 6th grade science teacher pointed out, some classes could not handle highly engaging activities or activities that gave the students a large amount of freedom. If this was done, either the students got so excited that they became a behavior issue or their lack of maturity prevented them from staying on task. Other classes may have many students with gaps in their foundational understanding of science and activities that were not heavily guided by the teacher easily frustrated students and led to behavior problems.

Lastly, I found that teachers selected activities that either highlighted their strengths on the topic or masked their weaknesses, when they existed. Teachers' comfort level with concepts determined how they chose to teach the topics. I found that teachers selected more engaging activities or tended to lecture more when they fully understood a concept. When their own knowledge lacked, they selected activities that shifted the class from being teacher-centered by having students read on their own from the book and answer questions, complete worksheets, and watch videos. This allowed the teacher to "cover" the material and quickly move on to more comfortable topics.

4.7 Mini Case Studies (pseudonyms are used for teacher names)

8th Grade - Mr. Johnson

Mr. Johnson was an eight-year veteran teacher. He taught high school life science courses for five years, which included general science, zoology, botany, and genetics. For the past three years, he taught middle school integrated science. He admitted that he had been forcing students to learn via ways that suited him best as the teacher. He indicated that incorporating visuals would benefit his students and that as a teacher he should focus on tailoring his lessons to the ways in which his students learn best, instead of forcing them to learn the way he taught. This frame of mind drove his teaching philosophy which he deemed as "they will get it however I teach it" approach. At that time, he believed the students should have catered their learning style to how he taught, not the other way around. During the interview, Mr. Johnson admitted that he did not use visualizations during instruction. Later in the interview, he disclosed that he strayed away from using technology and visualizations because he felt uncomfortable with them and felt his skills lacked in that area. Mr. Johnson's learning style was auditory and his primary method of instruction was lecture.

Mr. Johnson completed a card sorting task in which he was asked to rate the topics of the eighth grade science curriculum in order from easiest to teach to most difficult to teach based on his own knowledge. The results are shown in Table 4.4. His results indicated that renewable and nonrenewable resources was a topic that was relatively easy for him to teach. This topic also had the highest percentage of learning activities that incorporated visualizations. In the weather unit, 50% of the instructional activities included visuals even though it was difficult for him to teach. For the other topics, about one-third of the learning activities were visualization-based. Mr. Johnson's most difficult topic to teach was plate tectonics and had the smallest percentage of visualization-based learning activities.

Table 4.4
Analysis of Science Topic Difficulty and Visualization Integration

Science Topic	Science Discipline	% of Instructional Activities That Were Visual
Renewable and Nonrenewable Resources	Earth Science	50
Periodic Table	Physical Science	33
Forces	Physical Science	31
Ecosystems	Earth Science	37
Astronomy	Earth Science	38
Inquiry	n/a	31
Weather	Earth Science	50
Plate Tectonics	Earth Science	6

Note. Eighth grade science content areas are listed in order of easiest to teach to most difficult to teach, as reported by the eighth grade teacher.

Although Mr. Johnson's background was biology and he indicated that Earth Science was his most difficult discipline to teach, data indicated there was no correlation between the use of visualizations and the science discipline. Mr. Johnson's data led me to infer that 30-35% of visualization-based activities is the norm for him.

Content areas were analyzed based on whether or not the topic was abstract. In science and science education, abstract topics have often been associated with increased visualization use. The percentage of instruction that included visualizations were also considered as it related to the teacher's level of difficulty to teach the topic (See Table 4.5).

Table 4.5
Abstract and Nonabstract Topics Verses Visualization Integration

Science Topic	Abstract or Nonabstract Topic	% of Instructional Activities That Were Visual
Renewable and Nonrenewable Resources	Abstract	50
Astronomy	Abstract	38
Plate Tectonics	Abstract	6

Table 4.5 Continued

Ecosystems	Nonabstract	37
Periodic Table	Nonabstract	33
Weather	Both	50
Forces	Both	31
Inquiry	n/a	31

Note. Science content areas are grouped by whether they are abstract or nonabstract. Periodic Table is labeled as nonabstract due to the content and skills embedded in the standard. In Grade 8, students are only required to analyze the position of elements on the periodic table and infer reactivity and general properties.

Based on the obtained data, there was no distinct link between how concrete or abstract a topic was and the percentage of learning activities that were visual. Mr. Johnson rarely graded students' visual products and when he did, he gave the students a passing score if they explained their product, regardless of the degree of accuracy. If students' justifications were inaccurate, he would correct the misunderstanding but the students' scores were not adjusted.

7th Grade - Miss Dean

Miss Dean was in her seventh year as a middle school science teacher. Among the three teachers, she used the most technology-based instructional resources. She dedicated time to find science-based movies, activities on iTunes University, interactive websites, and other internet resources to integrate into her instruction.

She described her teaching philosophy as "creative chaos." She preferred for her students to have the freedom to create products in her class. Her students were often tasked with drawing science concepts and creating models. During her interview, she indicated that she used visualizations two or three times per chapter. She found it difficult to integrate student-made visual activities into her daily instruction when the school changed the time of classes from 90 minutes to 52 minutes. With the change from block schedule (90 minutes) to periods (52 minutes), she felt she didn't have enough time to introduce topics and allow students the time needed to develop visual products. She indicated that she did not do a thorough job of planning her lessons ahead of time. Her learning style was kinesthetic and her primary method of instruction was through note taking and the creation of student products.

Table 4.6
Analysis of Science Topic Difficulty and Visualization Integration

Science Topic	Science Discipline	% of Instructional Activities That Were Visual
Inquiry	n/a	52
Properties of Matter	Physical Science	41
Earth's Rotation and Revolution	Earth Science	47
Classification of Living Things	Life Science	80
Atoms	Physical Science	50
Astronomy	Earth Science	36
Genetics	Life Science	58
Electricity	Physical Science	43
Chemical Reactions	Physical Science	0
Law of Reflection and Refraction	Physical Science	17
Plate Tectonics	Earth Science	20
Heat Transfer	Earth Science	26
Weather	Earth Science	33

Note. Seventh grade science content areas are listed in order of easiest to teach to most difficult to teach, as reported by the seventh grade teacher.

Miss Dean also completed the card sorting task and organized the seventh grade topics in order of increasing difficulty. There was no noticeable trend in relation to ease of teaching a topic and the amount of learning activities that were visual. This was assumed to be because although some of the topics were more difficult for her to teach, she had a philosophy that included a process of allowing students to be creative and to create products in class. This made her class more student centered and masked her own weaknesses on topics. Even in areas of her own content-based weaknesses, she was able to have students take charge of their own learning through visual products such as creating posters, scenarios, and models. However, with the exception of astronomy, there was still more visual activities embedded in the lessons of those topics that were the easiest for Miss Dean when compared to more difficult topics. Because majority of the topics covered by her were abstract, I was unable to draw any correlations between degree of abstractness and the percentage of visuals that were used to teach the concept (Table 9). Her method for grading such activities was based on effort. If the student met a predetermined minimal criterion and showed that some learning occurred, the student received a passing grade

Table 4.7
Abstract and Nonabstract Topics Verses Visualization Integration

Science Topic	Abstract or Nonabstract Topic	% of Instructional Activities That Were Visual
Genetics	Abstract	58
Atoms	Abstract	50
Earth’s Rotation and Revolution	Abstract	47
Electricity	Abstract	43
Properties of Matter	Abstract	41
Astronomy	Abstract	36
Heat Transfer	Abstract	20
Plate Tectonics	Abstract	20
Law of Reflection and Refraction	Abstract	17
Chemical Reactions	Abstract	0
Classification of Living Things	Nonabstract	80
Weather	Both	33
Inquiry	n/a	52

Table 4.7 continued

Note. Science content areas are groups by whether they are abstract or nonabstract. Periodic Table is labeled as nonabstract due to the content and skills embedded in the standard. In Grade 8, students are only required to analyze the position of elements on the periodic table and infer reactivity and general properties.

6th Grade - Miss. Watson

Miss Watson had been a middle school teacher for nine years. She taught seventh grade science for most of those years. She had previously taught health and sixth grade Math. This year was her first year teaching sixth grade science. Miss Watson's teaching philosophy was that every child had a way of learning, and it her job to make sure her lessons integrated those ways. Her learning style was kinesthetic and her primary method of instruction was through demonstrations, mini labs, and note taking. Her science background was biology and she had recently completed a three year, Physical Science and Earth Science summer program for teachers. She used a lot of the techniques from that program in her classes.

Miss Watson spent a lot of time designing activities based on the previous day's lesson and the gaps in understanding she felt students had. She was one of the few science teachers at the school who frequently allowed her students to complete lab activities, typically once a week. She also believed that students learned best by hearing it, reading it for themselves, and then duplicating what she modeled for them. She completed the same card sort task for sixth grade topics.

Table 4.8

Analysis of Science Topic Difficulty and Visualization Integration

Science Topic	Science Discipline	% of Instructional Activities That Were Visual
Cells	Life Science	50
Earth's Rotation and Revolution	Earth Science	43
Heat Transfer	Earth Science	37
Inquiry	n/a	33
Astronomy	Earth Science	35
Genetics	Life Science	36
Animal Adaptations	Life Science	33
Forces/Motion	Physical Science	33
Weather	Earth Science	41
Health Care Technology	Life Science	0

Note. Grade 6 Science content areas are listed in order of easiest to teach to most difficult to teach, as reported by the Grade 6 teacher.

For Miss Watson, topics such as cells, and Earth's rotation and revolution were among the easiest for her to teach. Other topics such as forces, weather, and health care technology were the most difficult for her to teach. Similarly to Mr. Johnson, the easier topics for her to teach had a higher percentage of learning activities that incorporated visualizations (with the exception of weather) (See Table 4.8). On average, 35% of her learning activities were visualization-based.

Table 4.9

Abstract and Nonabstract Topics Verses Visualization Integration

Science Topic	Abstract or Nonabstract Topic	% of Instructional Activities That Were Visual
Earth's Rotation and Revolution	Abstract	43
Heat Transfer	Abstract	37
Genetics	Abstract	36
Astronomy	Abstract	35
Animal Adaptations	Nonabstract	33
Health Care Technology	Nonabstract	0

Table 4.9 Continued

Cells	Both	50
Weather	Both	41
Forces/Motion	Both	33
Inquiry	n/a	33

Note. Science content areas are groups by whether they are abstract or nonabstract. Periodic Table is labeled as nonabstract due to the content and skills embedded in the standard. In Grade 8, students are only required to analyze the position of elements on the periodic table and infer reactivity and general properties. Whether a topic was listed as abstract or non-abstract was based on the specific concepts that were listed in the curriculum for that grade level. For example, while the phenotypes of non-abstract components of genetics, at the sixth grade level, genetics covers an introduction to DNA, chromosomes, and alleles of which are abstract based on the resources teachers have to cover the material.

Also, the amount of visualizations incorporated into a lesson was not correlated with a particular science discipline or the degree of abstractness of the topic (See Table 4.9). Her primary method for grading student's visual products was through rubrics.

4.8 Summary

This chapter looked in depth at the data collected during the research project. The aim of the project was to determine the facilitators and barriers of visualization use by middle school science teachers. The goal of the project was to answer distinct questions that aided in the development of a theoretical framework that described and explained visualization use at the middle school level.

The first subquestion looked at middle school science teachers' views on visualizations as an instructional tool. Results indicated that teachers saw visualizations as an added benefit to their instructional repertoire and visualizations also assisted students in making connections between concepts. Secondly, the methods in which teachers felt students learned best were analyzed and data indicated that teachers contributed hands-on and visually engaging activities as being better suited for middle school learners. But, visualizations received mixed reviews as it related to the ease of planning for and integrating visualizations into daily instruction. Our third subquestion, which looked at the types of training teachers received indicated that overall, teachers had no formal training or workshops on visualizations. However, this did not sway their beliefs on how visualizations could support instruction. Additional factors that that had an effect on the integration of visualizations into instruction included students' background knowledge, classroom dynamics, time, and the teacher's comfort level.

CHAPTER V – CONCLUSIONS AND IMPLICATIONS

5.1 Introduction

The final chapter of this study seeks to connect the results of the study with supporting data found within the science education research community. Each research question is evaluated individually and specific connections to the literature is made to assist the reader in understanding the phenomenon. Using both the research data and the literature collaboratively, a theoretical framework will be suggested.

The main research question I sought to answer was:

What are the barriers and facilitators that guide visualization-based instruction by middle school teachers in science classrooms?

The following sub-questions were addressed:

1) How do middle school science teachers view visualizations as an instructional tool compared to other instructional tools?
2) How are middle school science teachers planning for and using visualizations in the classroom?
3) What types of training have middle school science teachers obtained in the use of visualizations as an instructional tool?
4) What factors influence the use of visualizations in the middle school science classroom?

5.2 Summary of the Study

The study was qualitative in nature and was based upon Grounded Theory theoretical framework and methodology. Data sources included teacher interviews, submitted lesson plans, card sorting tasks, classroom observations, teachers' learning style inventories, and analysis of classroom artifacts. All data was triangulated and coded, trends were identified, and a substantive theory was developed.

5.3 Research Question One

The first subquestion asked: How do middle school science teachers view visualizations as an instructional tool compared to other instructional tools?

As teachers mentally prepare for instruction and make decisions on which strategies to include in their lessons, they must consider methods that best engage learners. All learners do not learn in the same manner and learning activities should be designed to suit multiple learning styles (Marbach-Ad, McGinnis & Dantley, 2008). Knowledge about how students learn, teachers' beliefs about the content and their own self-efficacy plays a role in how they go about selecting instructional activities (Jeanpierre, 2007; Williamson, Brown, Peck & Simpson, 2005). In addition, In this study, teachers indicated that they viewed visualizations as a resource that assisted them in supporting multiple learning styles. They also viewed visualizations as a tool that helped students organize and make connections between of a variety of concepts, both simple and complex. This viewpoint was also seen in research done by Ferreira & Baptista (2013). Their research showed that teachers viewed visualizations as a vessel to make concepts easier to understanding and to improve comprehension. It was recognized as adding engaging elements to their classes.

Overall, our research shows that teachers possessed positive views of visualizations but support for the integration of visualizations into the classroom lacked. Teachers who shared positive views of technology-infused classrooms and student-centered instruction were more likely to integrate technology and tools such as visualizations into their classrooms (Chang, 2011). This study's results indicated this as well. This study's results aligned with results shown by other studies that indicated the best strategies for implementation of visualizations within the classroom were still developing (Ferreira & Baptista, 2013).

5.4 Research Question Two

The second subquestion asked: How are middle school science teachers planning for and using visualizations in the classroom?

While visualizations were held in high regard for helping students learn and in facilitating the instructional process for teachers, results indicated that teachers used visual components in majority of their planning and instructional processes but in less than a third of their assessments. This is believed to be linked to the lack of formal training on how to incorporate visualizations into instruction. This was the case with Mr. Johnson. During his interview, he indicated that students learned best by being able to visually connect his lectures with the concept, but he strayed away from using visuals because he was uncomfortable with them. This falls in line with current research done by Hakverdi-Can (2012) where they saw a divide in teachers' use of visualizations. Overall, teachers' use of technology and visualizations have increased over the past few decades, but there were distinct groups of teachers that have not increased in visualization use or have done so marginally.

While data from this research study indicated that two of the three teachers preferred engaging classes, they primarily used technology and textbooks to plan and implement their lessons. It would be elusive to believe that middle school students were conducting experiments every day. Manipulatives and resources received from workshops were integrated into lessons but composed only part of daily lessons. This study's data indicated that technology with embedded visualizations were one of the top resources listed by teachers. There were used for instructional videos, as simulations, to view demos and for other activities. This supports the findings from Williamson, Brown, Peck & Simpson (2005) where they concluded that many of the visualizations that were used in middle school classrooms were premade and accessed via the internet. Other commonly used visualizations included videos and PowerPoints, which are also premade (Williamson et al., 2005).

Results of this study indicated that majority of the visualizations used in middle school classes, whether created or premade, were used with low cognitive activities such as organizing information, labeling, and identifying trends. Although two of the teachers used visualizations frequently in their classes, only one had identified a specific method for assessing students' work with them. Although interviews indicated that teachers would ideally like to use visualizations more often, their lesson plans indicated that other activities, such as worksheets and reviewing the textbook took precedence. Williamson et al. saw similar results in their study (2005).

5.5 Research Question Three

The third subquestion asked: What types of training have middle school science teachers obtained in the use of visualizations as an instructional tool?

Most students cannot benefit from visualizations if their teachers do not know how to use them (Williamson et al., 2005). In both the pilot study and the current study, teachers had very limited and in most cases, no training on how to incorporate visualizations into instruction. However, majority of teachers used visualizations and on their own, had determined how to best integrate them into their class structures. This study's data indicated that visualizations can have a greater impact in the classroom if teachers received specific training on how to identify the types of visualizations that are best suited for a variety of instructional settings. Teachers need dedicated time to learn best practices for visualization use, get acclimated with their use, troubleshoot their use with actual students, and receive additional support (Williamson, Brown, Peck & Simpson, 2005). Teachers who wish to create their own visualizations also need design knowledge to know what aspects of visualizations are necessary and what hinders student understanding (Linn, 2008).

5.6 Research Question Four

The fourth subquestion asked: What factors influencing the use of visualizations in the middle school science classroom?

A link between teacher performance and their instructional beliefs has already been established in the research community indicating that a teacher's beliefs and experiences directly impact all aspects of instruction including lesson planning, assessments, evaluations, and their decision-making process within the classroom (Marbach-Ad et al., 2008). Nespor indicated that a teacher's previous experiences served as the guide through which experiences are channeled (Marbach-Ad et al., 2008). This indicates that teachers were more likely to structure lessons in the same ways lessons were delivered to them. They also used the same methods and strategies from previous lessons and adjusted their instructional methods only when they had been guided through the steps to make such changes. Otherwise, a teacher may be resistant to change (Marbach-Ad et al., 2008).

Several researchers have students the factors that influence teachers' use of computer-aided technology in the classroom. Major factors currently found included:

- personal self-efficacy in teaching with computers,
- outcome expectancy,
- classroom management,
- age,
- gender,
- teaching experience,
- personal and professional computer use, and
- science teacher's knowledge/skills in using such tools.

Data from this study parallels factors found to be associated with computer-aided technology. For our study, additional factors included student knowledge, individual learning needs, time, curriculum, classroom management, and the teacher's self-efficacy with using the material, in that order.

5.7 Main Research Question

The main research question for this study was: What are the barriers and facilitators that guide visualization-based instruction by middle school teachers in science classrooms. From the data collected during this study, barriers that hindered the utilization of visualization-based instruction were:

- time,
- teacher's comfort level with visualizations,
- students' comfort levels and prior experiences with visualizations,
- teacher's learning style, and

- the teacher’s teaching philosophy.

Facilitators of visualizations-based instruction were:

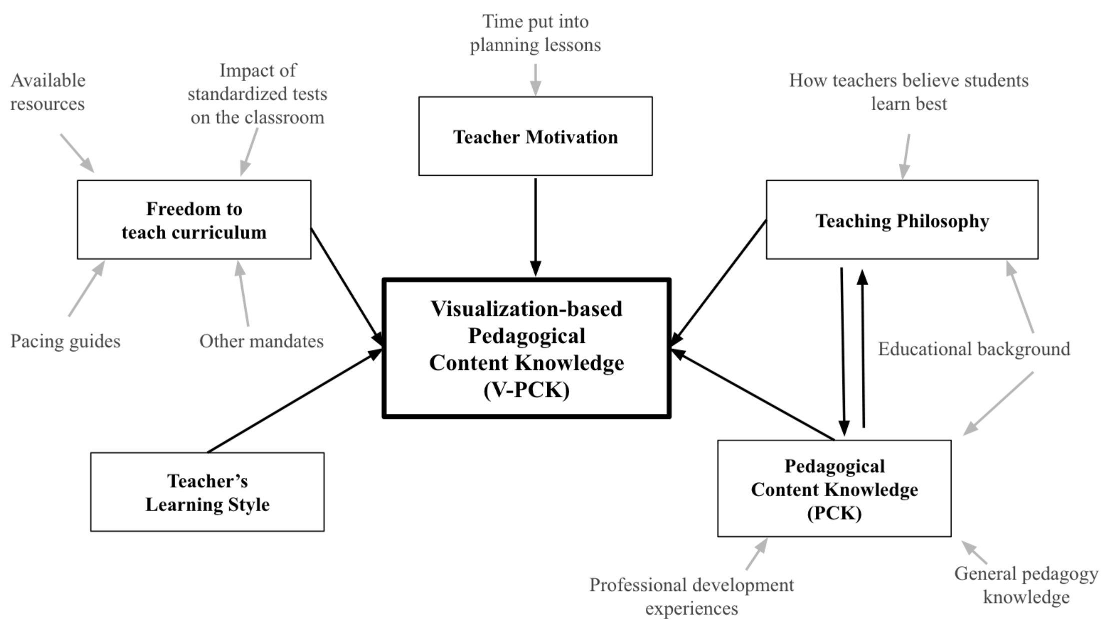
- prior exposure to teacher trainings on visualizations in the classroom,
- teachers’ understanding of how students learn and how to support those ways though instruction, and
- a willing attitude.

5.8 Development of V-PCK

Teachers are using visualizations more than they have in the past (Ferreira, Baptista & Arroio, 2011). Therefore, it is appropriate that a theory should exist that explain science teachers’ experiences with visualizations in the classroom. This study was designed to understand the barriers and facilitators that directly impact visualization use in the middle school science classroom and has led to the formation of the following theory, Visualization-based Pedagogical Content Knowledge (V-PCK). It was created from data that was strategically collected, coded, and analyzed via grounded theory methodology. Visualization-based Pedagogical Content Knowledge also highlights relationships among numerous factors to explain teachers’ experiences. It should serve as a fundamental framework to build upon and explain future research.

Figure 5.1

Tenets Comprising Visualization-based Pedagogical Content Knowledge (V-PCK)



Note. Visualization-based Pedagogical Content Knowledge (V-PCK) is based upon five tents which are influenced by a multitude of factors.

Data from the current study indicated that five major categories contributed to Visualization-based Pedagogical Content Knowledge (V-PCK). These categories were:

- Pedagogical content knowledge (PCK),
- teaching philosophy,
- teacher's learning style,
- teacher motivation, and
- freedom to teach curriculum.

Pedagogical Content Knowledge, as developed by Lee Shulman and further refined by Julie Gross-Newsome, is one of the major components of V-PCK. Data from this study indicated that teachers' knowledge of general pedagogy, their collective professional development experiences, and their educational background influenced their pedagogical content knowledge. This in turn influenced their V-PCK. Also, teachers that comfortably integrated technology into their classes and/or had classes that were student-centered displayed a higher level of V-PCK than their counterparts. V-PCK is derived from the Transformative model of PCK. The Transformative model is viewed as a complete blending of the individual components such that a new knowledge, PCK, is developed as opposed to the traditional PCK model in which each of its individual component are still identifiable when observed in the classroom.

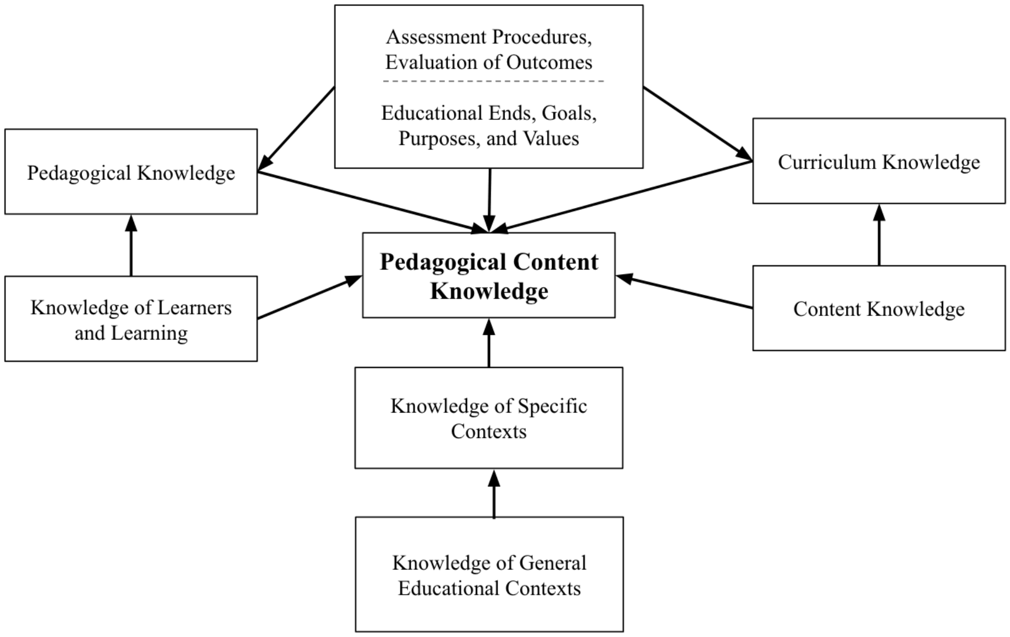
This study found that the teaching philosophy was influenced by the teacher's pedagogical content knowledge, their beliefs about how students learned best, and by their educational background. Their teaching philosophy drove their views on how lessons should be designed and their level of PCK dictated, in part, which instructional methods were at the forefront of the lesson planning process. These influences were present whether teachers used visualizations to drive instruction or whether students' visualizations-based activities were designed to mask teachers' weaknesses. Data from this study also suggested that teachers' PCK and teaching philosophies directly influenced each other.

The teacher's learning style served as a category of V-PCK. Teachers tended to develop lessons that catered to their own learning styles. In order to meet the needs of a diverse classroom, teachers had to be intentional about designing lessons that addressed multiple learning modalities.

The degree of freedom a teacher believed they had over their course also influenced V-PCK. These influences included access to resources such as those that allowed easy integration of visualizations into lessons, district mandated documents such as curriculum and pacing guides, the impact of standardized tests on the classroom and the teacher's views of how classroom dynamics should be designed to address standardized assessments.

The last component that influences V-PCK is teacher motivation. Whether or not teachers had training on integrating visualizations into the classroom, time was needed to acquire or create visualizations. It also took time to acclimate students to visualizations-based activities if they haven't been previously exposed to those types of activities. Teachers must be cognizant of their own learning styles and their strengths and weaknesses with the content in order to design lessons that supports the needs of all students in their classes. If teachers feel like time is an issue or that they don't have the knowledge or resources to development visualization-based lessons, they will not be used.

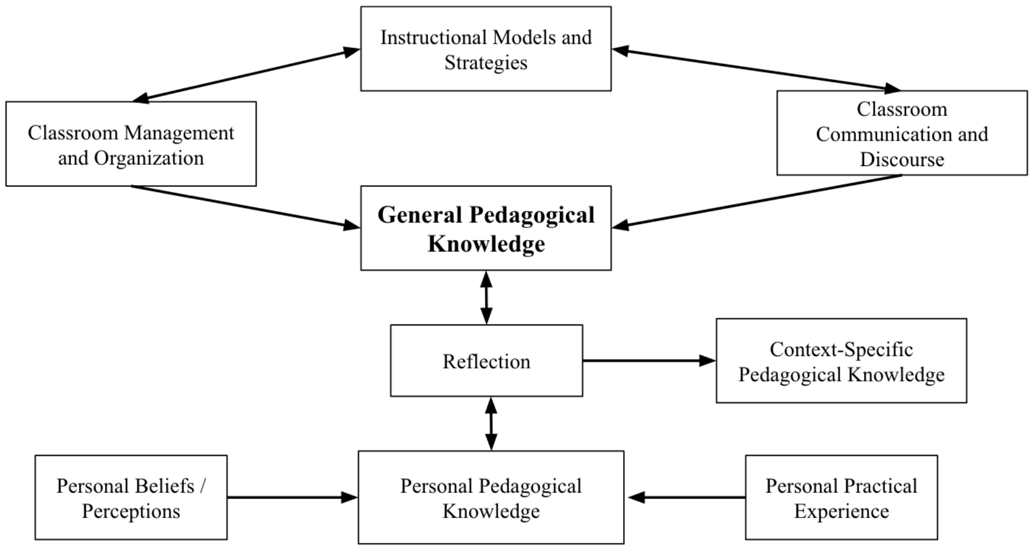
Figure 5.2
Categories Contributing to Pedagogical Content Knowledge



Reference: Gess-Newsome, J., & Lederman, N. (1999). *Examining pedagogical content knowledge*. (Vol. 6). Boston, Massachusetts: Kluwer Academic Publishers.

When the tenets of V-PCK were compared to the categories that contributed to Pedagogical Content Knowledge, V-PCK tenets aligned with the categories that contributed to Pedagogical Content Knowledge with the following exceptions (See Figure 5.2). This study found that assessment procedures and evaluation of outcomes impacted the teachers' freedom to teach the curriculum as opposed to being a direct influencer of PCK. This study also associated educational ends, goals, purposes, and values as contributing factors of teaching philosophy and PCK.

Figure 5.3
Facets of Pedagogical Knowledge



Reference: Gess-Newsome, J., & Lederman, N. (1999). *Examining pedagogical content knowledge*. (Vol. 6). Boston, Massachusetts: Kluwer Academic Publishers.

We saw alignment with the facets of general pedagogy knowledge as it related to our study with one exception, we found that reflection comprised teacher motivation, teaching philosophy, as well as general pedagogical knowledge (See Figure 5.3).

5.9 Implications

This study could impact the ways in which professional development opportunities are designed for middle school science teachers. Based on the National Research Council, part of the goal of science is to support science literacy among all students. Science teachers today are tasked with providing students with the science skills needed to make informed decisions in everyday life (National Research Council, 2012). This includes being able to interpret visualizations such as charts, graphs, and simulations in order to make informed decisions. Therefore, those factors that directly influence how teachers plan for visualizations and the ways in which visualizations are integrated into classroom instruction can have a direct influence on meeting this goal.

This study could also impact future studies on science education by providing a theoretical framework which adequately addresses the use of visualizations in the classroom.

5.10 Confounds

It is possible that a number of confounds were present that may have influenced the data that was collected. These confounds may have included the effect of my presence during classroom observations. Although I served as the participants' instructional coach for two years prior to the start of the research project, my presence in their classrooms may have caused the participants to spend more time than usual to prepare lessons. It is also possible that my presence during classroom observations may have caused increased stress or nervousness, which may have caused the teacher to forget to integrate a planned visualization or other instructional resource.

It is possible during interviews and during the cart sort activities that participants gave responses that they thought would be ideal responses. Participants may have given responses that were embellished in order mask weaknesses in their own content knowledge, planning methods, or instructional strategies.

No homework assignments were considered for this study due to inconsistencies in it being assigned by the participants and due to inconsistencies in students completing the homework and returning it to the assigning teacher.

Lesson plans and classrooms observations where students were assessed or taken to the library were not analyzed.

5.11 Recommendations for Future Research

Since visualizations at the middle school level is underrepresented by visualization research, more research should be conducted to support the continued development of Visualization-based Pedagogical Content Knowledge Theory (V-PCK). For future studies, the following components should be considered.

This study consisted of an in depth look at three science teachers, their instructional practices, and planning methods. In future studies, it would be ideal to replicate the study and include a larger sample size of middle school science teachers. This would allow more data to be collected and analyzed such that the theory could be further solidified.

The second recommendation would be to collect additional data on the types of visualizations that are used by teachers (e.g. static, animations, manipulatives, teacher created vs commercially made) and their integration into the science middle school classrooms. This would allow the researcher to determine if certain types of visualizations are used more frequently than others, at which points in the lesson, and with which science topics (such as genetics, animal adaptations, plate tectonics, and astronomy).

The third recommendation would be to analyze pre-service teacher programs and regional and nationwide professional development opportunities to examine ways in which these programs addressed visualization use in the classroom. This would provide valuable insight into views on visualizations as pre-serve teachers enter the classroom.

APPENDIX A - Consent from Participating Middle School

Edward Buck, Ph.D., Principal
Joanna Mcmurtry, Assistant Principal

Jackson Public Schools

ebuck@jackson.k12.ms.us
Phone (601) 987 - 8360
Facsimile (601) 981-7026

Institutional Review Board
The University of Southern Mississippi
118 College Drive #5147
Hattiesburg, MS 394

December 7, 2011

To Whom It May Concern,

The Science instructional coach, Jacqueline Samuel, has informed me of her desire to conduct a research study at Kirksey Middle School. The purpose of the study is to collect data on teachers' experiences with visualizations at the middle school level. The study will focus strictly on teachers within the building and no data will be collected from students. The study will take approximately eight weeks for data collection which will consist of teacher interviews, classroom observations, and collecting information from submitted lesson plans.

She has reviewed the protocols and procedures of the study with me and I give her permission to conduct this study at Henry J. Kirksey Middle School. If additional information is needed, please do not hesitate to contact me at ebuck@jackson.k12.ms.us or (601) 987-8360.

Educationally,

Edward Buck

Edward Buck, Ph.D.
Principal

JACKSON PUBLIC SCHOOL DISTRICT
Henry J. Kirksey Middle School **5677 Highland Drive** **Jackson, MS 39206**

APPENDIX B - IRB Approval Letter

THE UNIVERSITY OF
SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.6820 | Fax: 601.266.4377 | www.usm.edu/irb

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: **13061201**
PROJECT TITLE: **Secondary Teachers' Experiences with Visualizations in the Middle School Classroom**
PROJECT TYPE: **Dissertation**
RESEARCHER(S): **Jacqueline Samuel**
COLLEGE/DIVISION: **College of Science and Technology**
DEPARTMENT: **Center for Science and Math Education**
FUNDING AGENCY/SPONSOR: **N/A**
IRB COMMITTEE ACTION: **Expedited Review Approval**
PERIOD OF APPROVAL: **07/25/2013 to 07/24/2014**

Lawrence A. Hosman, Ph.D.
Institutional Review Board

APPENDIX C - Prompt for Introduction of Research Project to Potential Subjects

Good afternoon, everyone. I don't believe there is anyone here who does not already know but, in the event you don't know, let me introduce myself. My name is Jacqueline Samuel, and I am the Science Coach and Interventionist here at Kirksey Middle School. I am currently in the final stages of a graduate program at The University of Southern Mississippi. I am working on a Ph.D. in Science Education with an emphasis in Biology Education.

I am beginning a research project in which I look at teachers' experiences with visualizations (or various forms of visuals as tools for teaching and learning). I invite each certified teacher here to participant in my study.

The study is explained in the consent form which has been handed to you. Please refer to it as I describe the study to you. (*Researcher reads the information from the form*).

Does anyone have questions you would like to ask concerning the study? (*Researcher will wait for questions*) If you would, please sign on the back which indicates that you are willing to volunteer to participate in the study. Please know that if you decide to participate in the study, there will be no added work benefits for you. Also, I need you all to understand that you are not required to participate in this study and if you decide not to participate that there will be no loss of work privileges, no loss of any kind of work benefits, and no associated repercussions.

If you have any questions and feel uncomfortable asking them here, you are welcome to ask me in a more private setting and offer your consent at that time.

Thank you for your time and cooperation.

APPENDIX D - Informed Consent for Participants

Purpose:
The goal of this study is to learn more about teachers' experiences with visuals in middle school classrooms.

Description:
You will be asked to participate in an interview which may take approximately 30-45 minutes. Once the interview has been completed, the researcher will visit your classroom to make observations throughout the term. The researcher will not interact with you or the students during this time. After each classroom visit, you may be asked to have another interview. You will also be asked to forward a copy of your lesson plans to the researcher. After the interviews, classroom visits, and overview of lesson plans, the data collected will be analyzed for patterns and trends. You will not be identified in any reports or discussions regarding the data.

Benefits
There are no specific benefits offered to the participants.

Risks
There are no foreseeable psychological or physical risks expected as a result of participating in this study, and you may withdraw from the study at any time during the process without any penalty.

Confidentiality Alternative Procedures
You are guaranteed confidentiality. The researcher will not identify any participant by name in reports stemming from the research project. All written and electronic notes, audiotapes, transcribed tapes, and copies of lesson plans will be stored in a locked file cabinet at the apartment of the researcher at 6675 Old Canton Rd. #2092, Ridgeland, MS 39157. Only the researcher and advisor will be able to see the original transcripts. All electronic data including audiotapes and electronic documents will be destroyed after the study is completed. Data representative of the group as a whole and/or pseudonyms will be used reporting.

Subjects' Assurance
Your participation in this study is entirely voluntary. You may decline to answer any question at any time and you may withdraw yourself from the study at any time without

penalty. The information gathered will be kept confidential along with your identity. All information will be destroyed when the study is completed.

Contact Persons

Questions concerning the research should be directed to Jacqueline Samuel at (601) 212-6473. The project and this consent form have been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research subject should be directed to the Administrator, Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406, (601) 266-6820.

Legal Rights and Signature

You will receive a copy of this consent form. You are not waiving any legal rights by signing this consent form. Your signature below indicates that you agree to participate in this study.

____ _______________

Name of the Research Subject (Print) Date

____ _______________

Signature of the Research Subject Date

____ _______________

Signature of Person Explaining the Study Date

APPENDIX E - Pre-Observation Interview Questions - Semi Structured

Overview script:

Thank you so much for participant in this study. As mentioned earlier, my goal is to gain a better understanding of experiences teachers might have with images. Your willingness to open your classroom environment to me in addition to our interviews will be very beneficial to this research project.

Would it be okay if I recorded our interview sessions? This will allow me to be able to better capture your response. Your name will not be used in the study in any way. Feel free to share your experiences in all honesty. If I ask a question that you don't quite understand, please ask me to rephrase the question.

Do you have any questions? Let's begin.

Pre-Observation Interview Questions

1. How many years have you been teaching?
2. Which subjects have you taught?
3. What subject(s) are you currently teaching?
4. How do you determine what types of activities to incorporate into a lesson?
5. What kind of resources do you use in the classroom (including resources for planning?)
6. In what ways do you allow students to show their understanding of a taught concept?
7. What methods do you think help students learn best?
8. Describe some situations where you might allow students to create images to show understanding?
9. Describe some situations where you would use images, graphs, charts, and other visuals in the classroom?
10. Have you attended any classes or professional developments on visual use/ using images in the classroom?
11. I would like for you to rate the following based on effectiveness in helping students understand concepts. There are no right or wrong answers. As you rate the cards, please think aloud. (The following choices would each be presented on an index card. The five index cards would be mixed up in front of the interviewee and then they would be asked to place their responses in the preferred order.) (For this question, place in order of effectiveness and explain your answer)
    a. Having students discuss the concept or topic
    b. Having students watch a video about the concept or topic
    c. Having the students write about the concept or topic
    d. Having the students to create a chart, graph, and/or picture about the concept or topic
    e. Having the students to write and create a chart/graph/picture about the concept
12. How often do you use visuals in your instructional method?

a. What determines whether or not it gets incorporated into the lesson for the day?

13. If respondent uses visuals often in #12, ask: Compared to other instructional methods, how easy or hard is it to plan for the use of images in the classroom.
14. If respondent rarely uses visuals in #12 ask: What do you think are some main reasons why you decide not to incorporate or to sparingly incorporate visuals/images into your instructional methods and classroom activities?
15. What kinds of visuals do you typically use?
16. What effect, if any, do you think having students draw out responses, chart, graph has on their learning and understanding?
17. What are your methods for grading/assessing students' visual products?
18. Have you had any other experiences with visualizations as it relates to teaching and student learning?

Thank you so much for your time.

APPENDIX F - Lesson Plan Template

Lesson Plan (Grade __)

Teacher(s) **Date(s)** **Unit:**

Subject: Science		**Instructional Checklist**
Comp/Objective(s):		**Instructional Methods** ☐ Case studies ☐ Cooperative learning/small groups ☐ Discussion/Discussion Boards ☐ Discovery Learning ☐ Graphic Organizers ☐ Journals/Blogs ☐ K-W-L ☐ Learning Centers ☐ Role-play ☐ Scaffolding ☐ PBL/Inquiry ☐ Simulations ☐ Literature circle ☐ Storytelling/digital Storytelling ☐ Other (list)______________
Skills:		
Anticipatory Set:		
Input/Modeling:		
Guided Practice:		**Materials Used** ☐ Curriculum document ☐ Pacing guide ☐ Textbook pp. _________ ☐ Handouts ☐ SPMS ☐ Whiteboard/SMART Board ☐ Overhead/transparency ☐ Internet ☐ Writing/Journaling ☐ Calculators ☐ Maps ☐ Manipulatives ☐ Learning centers ☐ Computers ☐ Other (list)______________
Independent Practice/Affiliation:		
Closure:		
Checking for Understanding (throughout the lesson		**Evaluation:** ☐ Teacher-made test (attach) ☐ SPMS ☐ Observation ☐ Rubric (attach) ☐ Performance task(s) ☐ Written assignment
Technology:	**Homework:**	**Interventions:**

APPENDIX G - Lesson Plan Analysis Guide

What Teachers Are Having Students to Do as It Relates to Images
(From Lesson Plans)

Participant #	Grade Level	Objective	What Students Are Asked to Do	Purpose/Role	Notes

NOTES:

Teacher Planned Images (From Lesson Plans)

Part.	Grade Level	Obj.	Planned Visual	Purpose of Planned Visual	Notes

TOTAL # OF PLANNED ACTIVITIES:

OF PLANNED ACTIVITIES WITH IMAGES:

NOTES:

APPENDIX H - Post Lesson Plan Analysis Interview Questions

(SEMI-STRUCTURED)

1. How did you derive at these activities to teach this concept?
2. I noticed that you planned to use (non-visual strategies or activity) to teach (concept), were other options such (visual-based strategy or activity) were considered? Tell me about the process to decide to use (non-visual strategy or activity) for this (concept or activity).
3. I noticed that you planned to use (visual strategies or activity) to teach (concept), were other options such (non-visual strategy or activity) considered? Tell me about the process to decide to use (visual strategy or activity) for this (concept or activity)

APPENDIX I - Post Classroom Observation Interview Questions

(Semi-Structured)

1. I see that you used (specific instructional strategy or visual), how do you feel that went?
2. How would you describe your comfort level with (the strategy or use of specific visual)?
3. How was the final decision to use (specific strategy or specific image) determined?
    a. Did you consider other options in teaching this specific content?
4. How easy was it for you to plan to use (specific strategy or specific visual)?
5. During instruction, you used (specific strategy or image) which wasn't listed in your lesson plans. What prompted you to deviate from your initial plans?
6. In your lesson plans you planned to use (specific strategy or image) but decided not to use it during instruction. What caused you to change your mind?
7. Which part of the lesson was easiest for you to implement? What made it easier for you?
8. Which part of the lesson was most challenging for you to implement? What made it challenging?
9. Do you think you would use that visualization in the future when you cover that topic?
10. On a scale of 1-5, how stressful or frustrating was it for you to use (specific type of visualization). With 1 being not stressful and 5 being very stressful?

. Also ask teacher to rate other instructional strategies that was used during the instructional session

a. If experience was stressful, ask: Why do you think it was stressful or frustrating?

b. If experience was not stressful/ frustrating, ask: Why do you think the experience was not stressful/ frustrating for you?

APPENDIX J - Topics for Content-based Card Sorting Task

Sixth Grade Topics

- Astronomy
- Atoms
- Chemical Reactions
- Classification of Living Things
- Earth’s Rotation and Revolution
- Electricity
- Genetics
- Heat Transfer
- Inquiry
- Law of Reflection and Refraction
- Plate Tectonics
- Properties of Matter
- Weather

Seventh Grade Topics

- Astronomy
- Atoms
- Chemical reactions
- Classification of living things
- Electricity
- Genetics
- Heat transfer
- Inquiry
- Law of reflection and refraction
- Plate tectonics
- Properties of matter
- Weather

Eighth Grade Topics

- Astronomy
- Ecosystems
- Forces
- Inquiry
- Periodic Table
- Plate Tectonics
- Renewable and nonrenewable resources
- Weather

APPENDIX K - Final Interview Questions

(SEMI-STRUCTURED)

1. Describe some situations where you might allow students to create images to show understanding?
    a. Help me to understand why you would prefer to use images for those situations?
2. What do you think influences your decision to use or not to use a strategy in class?
3. What do you think influences your decision to use or not use visualizations in class?
4. Have you attended any classes or professional developments on visual use/visualizations in the classroom?
    a. If so, please describe the class/professional development.
5. Did your teacher preparation program focus on or introduce you to particular instructional strategies?
    a. Will you describe some of those strategies?
6. How often do you use visuals in your instructional method?
    a. If respondent uses visuals often ask: Compared to other instructional methods, how easy or hard is it to plan for the use of visuals/visualizations in the classroom.
        i. What kinds of visuals would you typically use during instruction?

ii. What determines whether or not it gets incorporated into the lesson for the day?

b. If respondent rarely uses visuals ask: What do you think are some main reasons why you decide not to incorporate or to sparingly incorporate visual/visualizations into your instructional methods and classroom activities?

7. What effect, if any, do you think having students draw out responses, chart, graph has on their learning and understanding?
8. What are your methods for grading/assessing students' visual products?
9. During the past few months, I've noticed that you appear more comfortable using (specific teaching style which may or may not be visualization-based), what do you think has led you to lean on that teaching style as your dominant way to teach?
10. I've also noticed that you tend to rarely use (specific teaching style which may or may not be visualization-based), what do you think has led you to stay away from that style?
11. When we interviewed earlier, you said that you believe students learn best by (response participant gave) but in your class students were given the opportunity to learn mostly by (participant's dominant way of teaching). Why do you think (participant's dominant way of teaching) shows up more in the classroom than (way participant said students learn best)?
12. Have you had any other experiences with visualizations as it relates to teaching and student learning?

13. Do you have any other information you would like to share regarding the use of images in the classroom or particular teaching strategies?

Thank you so much for your time and willingness to participant in this study.

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