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The Impact of an Interactive Simulation Program on English Language Learner Achievement in a Middle School Science Classroom

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Abstract

The purpose of this study was to determine how a particular technology program, Gizmos, would impact English language learner students in demonstrating their verbal and written comprehension of science content at a proficient level. Gizmos were incorporated as an intervention to facilitate the teaching of two different topics, convection cells and hurricane motion. This study involved three English language learner students with varying World-Class Instructional Design and Assessment (WIDA) proficiency levels between one and four. Semi-structured interviews, semi-structured observations, and work samples were conducted and collected from each of the participants. My analysis demonstrated a strong correlation between the use of Gizmos with English language learner's written and oral comprehension of science content. I conclude that interactive Gizmos simulations increase verbal and written comprehension of science content with middle level English language learner students. I also conclude that digital simulation games have a positive effect on ELL learner ability to understand science at a proficient level due to the visual connections that they provide that maximize comprehensible input.

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Chapter 1

Introduction

As a middle level science teacher for the past ten years, my focus has been to meet the needs of all sixth and seventh grade science students that come through my classroom. I took the time to receive a master's degree in education with additional endorsements in gifted-talented instruction, literacy, online teaching, and project-based learning to better meet these diverse needs. Teaching at this level, which includes student ages between eleven and twelve years old, requires developing an "experience for young adolescents that is both grounded in adolescent development (physical, social, emotional, moral, and cognitive needs) and engages students in relevant, integrated, challenging, and exploratory learning experiences" (DiCicco, Cook, & Faulkner, 2016, pg. 1).

During this time, I noticed that one group of students has consistently underperformed all other groups within the school. This group consisted of our English language learners (ELL) with reading and/or literacy scores between one and five. Level one students have minimal English proficiency, while level five students know and use social and academic language with on grade-level material. The World-Class Instructional Design & Assessment (WIDA) consortium (WIDA ACCESS Tests, 2020). designed categories the language acquisition of ELL students based on a comprehensive competency test that they take each year. Each ELL student takes an English Proficiency test (WIDA) when they enroll and each spring (WIDA ACCESS Tests, 2020). Each student receives a proficiency level in each domain (listening, speaking, reading, and

writing) based on their raw scores. Once the student achieves specific levels in all four domains, and meets additional district and state exit criteria, they will no longer be considered an ELL student and will not receive ELL services. Students who have an English Language (EL) status between one and five, based on scores from the WIDA ACCESS test, are considered to have limited English proficiency (LEP).

- 1 – Entering: Knows and uses minimal social language and minimal academic language with visual support
- 2 – Emerging: Knows and uses some social English and general academic language with visual support
- 3 – Developing: Knows and uses social English and some specific academic language with visual support
- 4 – Expanding: Knows and uses social English and some technical academic language
- 5 – Bridging: Knows and uses social and academic language working with grade level material

  (WIDA ACCESS Tests, 2020).

These students already have a range of academic supports being provided to them, including: Provision of a copy of the notes for each topic or completion of notes through a graphic organizer, use of a bilingual dictionary, extended time for assignments/assessments, and rewording of directions. When looking back at my different classroom assignments, I noticed that all levels of English language learners from one to five consistently had difficulty when specific academic vocabulary was

involved within a question. Students would attempt to answer the questions, but many would be consistently wrong on assignments. These data are from my own observations as a teacher within the classroom based on a variety of formative and summative assessments. In addition, these students reported guessing on most of the questions which contained specific academic vocabulary.

This made me go back to previous assignments through the year, with the same trend being identified. These students also tended not to use their bilingual dictionaries during assignments. When asked, most of these students stated that “it would take too long to look up each word” while a few stated that “they did not need them.” This made me begin thinking about the structure of the assignments themselves in terms of how appropriate they were in providing ELL students with learning input that was comprehensible without the need to focus on specific terminology or structure that may be impeded by language barriers.

Problem Statement

ELL students are underperforming their peers in the science classroom due to curriculum input that is not comprehensible based on student’s language acquisition levels. This sentiment is echoed with the statement that “teachers, professional developers, and curriculum designers must have better examples of how to support the teaching and learning of middle school ELL students in content-area instruction” (Gomez and Madda, 2005, p. 1). Vocabulary acquisition and integration is a complex process, with many teachers having misconceptions of student mastery of the language. Teachers often correlate mastery of conversational English with mastery of the language, which

can lead to instruction that does not account for students' lack of understanding with specific academic vocabulary. This is supported by Harper and Jong (2004) when stating that "teachers frequently report having observed ELL learners who seem to pick up the language needed for social purposes quickly and easily while they struggle with academic language and literacy" (pg. 154). In a sense, they often assume that students who can speak the language also understand specific terminology.

In addition, this issue is compounded with the types of resources and texts that are included within standardized curriculum. "Many science texts have multiple diagrams to help students understand key concepts. Unfortunately, the charts and visuals are often complex and require an understanding of key concepts and a great deal of text before they can be understood" (Gomez and Madda, 2005, p. 4). The type of input provided by these types of resources fails to account for how ELL students can interpret the visuals without language being a barrier in the process. In order to adequately account for this, input needs to be presented in a way that allows ELL students to make connections between what they know and what is being learned without impediment.

In addition, the number of ELL students within schools is increasing. "The population of students who are English language learners in the United States has increased dramatically over the last decade. They are currently one of the largest groups of students who struggle with literacy, specifically vocabulary and comprehension" (Weiland, 2017, p.14). When I first started teaching ten years ago, I had two ELL students across five science classes. This year, I have twelve ELL students. Since our schools' ELL population is below the level to directly impact our schools' state report card, many educators simply "let the ELL students pass" by grading them on completion

and providing them with very simplified assessments which are not on grade level. These types of strategies fail to address issues in existing instructional practices and only set the students up for failure in future grades. Incorporating comprehensible input into the curriculum for ELL students may help in improving their academic understanding and success.

Theoretical Framework

Cognitive constructivism and Krashen's theory both work in tangent to provide theoretical support to the idea of students learning through doing. The theory of cognitive constructivism was developed by both Jean Piaget and John Dewey. "Cognitive constructivism views learning as the process of constructing meaning; it is how people make sense of their experience" (Baker, 2019, p.1). Cognitive constructivism allows the students to develop meaning behind their experiences, constructing new knowledge by making sense of the world through active discovery. In order to facilitate this active discovery, educators take on the role of facilitators by "providing the necessary resources and by guiding learners as they attempt to assimilate new knowledge to old and to modify the old to accommodate the new" (Baker, 2019, p.1). Krashen's theory originated from the linguist Stephen Krashen who was developing his studies of five hypothesis on second language acquisition (Krashen, 2015). These hypotheses are the input hypothesis, the acquisition-learning hypothesis, the monitor hypothesis, the natural order hypothesis, and the affective filter hypothesis. Krashen's theory indicates that "second-language students acquire language competence by exposure to language that is both understandable and meaningful to them. By concentrating on meaning, they subconsciously acquire form" (Tricomi, 1986, p. 60). Krashen's theory implies that

activities used within the classroom for ELL students need to be presented in a way that is comprehensible through means that reduce or eliminate language barriers.

Krashen's theory can be viewed as branching off from the broad theory of cognitive constructivism, which emphases student centered learning through doing. This connection can be found in the cognitive constructivist concept that "learning is an active process throughout the learners' experiences and the environment in which they are learning. Accepting constructivist learning" (Alanazi, 2016, p.2). This construction of knowledge emphasizes the importance of connecting the already existing knowledge in learner's minds when learning new content. Krashen's hypothesis of comprehensible input mirrors this focus by allowing ELL students to construct new language based on experiences which allow them to naturally make these connections while minimizing language barriers in the process. This concept of making natural connections is also proposed in the statement that "this learning approach helps children to be guided by their curiosity when learning instead of being led by a large amount of instruction" (Alanazi, 2016, p.3). With cognitive constructivism and its connections to Krashen's theory of comprehensible input, this means that the teacher becomes the facilitator while the students become the center of the learning environment. However, the importance of this input being authentic to students cannot be overlooked. Authentic can be defined as input that "values students' interests and builds on what students already know by providing them with scaffolding instructions" (Alanazi, 2016, p.3).

Although there is debate on how much comprehensible input is required to facilitate the most effective environment for second language acquisition, Krashen himself states that "in the classroom, we can provide an hour a day of comprehensible

input, which is probably much better than the outside can do for the beginner" (Krashen, 2015, p.30). This coincides with the amount of time students spend in their classes within my school. I am using Krashen's theory of comprehensible input to conduct my research in order to further investigate how the incorporation of interactive digital simulations through the Gizmos program impact students' language acquisition. Technology itself plays a key role by "creating learning environments where comprehensive input contributes to the lowering of the learner's affective filter" (Diallo, 2014, p.16). Using cognitive constructivism and Krashen's theory as a guide will support designing instructional materials that make the concepts accessible regardless of language.

Purpose Statement

The purpose of this study was to determine how a particular technology program, Gizmos, would impact ELL students in demonstrating their verbal and written comprehension of science content. Gizmos incorporates interactive simulations for each topic taught in the middle level science curriculum. The visual nature of simulations are proposed to help reduce the language barrier between connecting prior knowledge to new learning by allowing the student to first comprehend the concept in their own way.

Research Questions

The following research questions were included to study the impact of Gizmos on English language learner comprehension:

1. How does the use of digital simulations provide opportunities for English Language Learners to develop understanding of content-specific vocabulary in middle school science?

2. What impact, if any, does a digital simulation game have on ELL learner ability to understand science at a proficient level (on a level with their peers of similar age/grade)

These specific research questions were selected due to the focus on how the intervention would impact ELL students' understanding of science concepts. Understanding will be defined as verbal and written comprehension of the concept in their own words followed by the association of content-specific terminology with the concept. Verbal and written comprehension were chosen together in order to provide a comprehensive view on the relationship between using interactive simulations with Gizmos and ELL students' ability to acquire the content. This particular type of intervention was chosen due to the programs ability to present science in a way that is interactive, reduces verbal and textual language barriers, and connects to prior knowledge and real-world experiences. My expectation is that the interactive Gizmos simulations will have a positive affect in helping ELL students learn the content to due a reduction in complex, text heavy instructional materials.

Significance of the Study

The significance of this research is to self-reflect on my own practices to make better instructional decisions that are cognizant to the needs of ELL learners and provide an opportunity to improve practice through a systematic approach to analyzing my own teaching practices in order to improve students' learning. An additional significance to this intervention-based study that uses practitioner-researcher is that the study will directly benefit the participating ELL students. Action research was selected for this

study since it allows me to focus on the needs of local ELL students by analyzing the impact of a specific intervention on their comprehension of science content. Since our ELL students have consistently underperformed all other groups within the school in demonstrating mastery to the science content, this study is necessary in identifying revised instructional practices that will aid in their comprehension.

While this study is intended to generate local, context dependent knowledge, it is not intended to be generalizable or demonstrate external validity. However, sharing practitioner-research can be evocative and transferable. Transferability can be defined as a process performed by readers who

> "note the specifics of the research situation and compare them to the specifics of an environment or situation with which they are familiar. If there are enough similarities between the two situations, readers may be able to infer that the results of the research would be the same or similar in their own situation" (Barnes, 2012, p. 3).

Evocative can be defined as researchers engaging with the topic of their study on an "emotional level by focusing on their passion before exploring the different research methodologies" (McConnell, 2014, p. 76). With evocation and transferability in mind, additional stakeholders may include other middle school science teachers who work with ELL students. These science teachers might gain a better understanding of how they can analyze their own instructional practices that are being used to facilitate teaching the content to ELL students and interventions that they may find useful in bridging achievement gaps in student comprehension.

Limitations of Study

Unanticipated constraints or challenges that may have an impact on the outcome of the study include ELL students being absent on the dates that the intervention occurred. In addition, limitations that might be inherent to the context or the problem itself include the focus on student comprehension of the concepts involved in science and not the specific vocabulary involved with the content. This limitation was addressed by using a prior knowledge data collection piece at the beginning of each Gizmo to gauge what students already knew about the content. This limitation was further addressed by organizing data collection methods in a way that supported students describing the content in their own words first, before learning and applying the content-specific vocabulary involved. Attempts have been made through design and theory to prevent the limitations identified at this early stage by incorporating the intervention into normal instructional practices, which typically consists of providing students with multiple days for labs and simulations to completed with a focus on flexible pacing. Incorporating cognitive constructivism and Krashen's theory strengthens the focus on students' demonstrating their understanding of the concept in their own words followed by the association of content-specific terminology with the concept. Data on students' verbal and written comprehension of the concepts were collected through multiple means and supported students' demonstrating this comprehension in multiple ways.

Organization of the Dissertation

This section of my dissertation, chapter 1, was designed to present the topic of study through a problem of practice, explain the topics importance and significance, describe the

theoretical connections, and briefly outline the methods that were involved with collecting and analyzing data to answer the research question. Chapter 2 will be an overview of existing literature involving science instruction and English language learners at the middle level. Connections to relevant studies that have used similar theoretical and methodological means to analyze interventions that attempt to provide scaffolds for students which support learning through the reduction or elimination of language barriers are also addressed. Chapter 3 will be used to describe the procedures used in conducting the study, including: Site and participants, data collection procedures, research role, and data analysis. Chapter 4 will be used to explain the findings gathered from the analyzed data through the identification of themes, categories, and patterns involved. Chapter 5 will report the conclusions that were drawn to answer the research question. To ensure that these conclusions are valid, they will be presented “objectively without interpreting them or expressing any value judgements” (Efron & Ravid, 2013, p. 228). In addition, discussion and implications of these conclusions will be presented on how they impact instructional practices for ELL students in a science classroom.

Purpose of Study

The purpose of this study was to determine how a particular technology program, Gizmos, would impact ELL students in demonstrating their verbal and written comprehension of science content. Gizmos were incorporated as an intervention to facilitate the teaching of two different topics, convection cells and hurricane motion. Additionally, this action research study was meant to determine what changes, if any, needed to be made to instructional practices to best meet the needs of English language learner students within my educational institution.

Table 1.1: Glossary of Terms

Term	Definition
English Language Learner	Students who are unable to communicate fluently or learn effectively in English, who often come from non-English-speaking homes and backgrounds, and who typically require specialized or modified instruction in both the English language and in their academic courses. (ENGLISH-LANGUAGE LEARNER, 2013)
Comprehensible Input	When the input is understood. (Krashen, 2015). Messages are made understandable and meaningful to the learner via a variety of techniques. (Maurer, 2020)
Cognitive Constructivism	Theory developed by Jean Piaget and John Dewey. "Cognitive constructivism views learning as the process of constructing meaning; it is how people make sense of their experience." (Baker, 2019).
Krashen's Theory	A set of five hypothesis developed by Stephen Krashen that are used to explain the acquisition of language for second language learners. (Krashen, 2015).
Practitioner Inquiry	A deep, thorough, exploration and understanding of complex phenomena that arise in practice. (Cochran-Smith & Lytle, 2009)

Action Research	A type of research that involves a systematic approach to analyzing one’s own practice to solve problems rather than develop theory. (Efron & Ravid, 2013).
World-Class Instructional Design & Assessment	Comprehensive competency test that ELL students take each year. Educators use results to make decisions about students' English academic language and to facilitate their language development. (WIDA ACCESS Tests, 2020).

Chapter 2

Literature Review

The problem of practice within this study is that ELL students are underperforming their peers in the science classroom due to curriculum input that is not comprehensible based on student's language acquisition levels. The purpose of this study was to determine how a particular technology program, Gizmos (ExploreLearning, 2022), would impact ELL students in demonstrating their verbal and written comprehension of science content. The Gizmos program utilizes interactive simulations for each topic taught in the science curriculum. Interactive simulations presented through Gizmos allow students to manipulate models using technology to collect data, analyze relationships, and make connections between stimuli within the natural world to construct new knowledge.

Teachers' misconceptions, such as correlating mastery of conversational English with mastery of the language, can lead to instruction that does not account for students' lack of understanding with specific academic vocabulary. In addition, many types of resources and texts used within the science curriculum have charts and visuals which first require an understanding of key concepts before they can be understood. The type of input provided by these types of resources fails to account for how ELL students can interpret the visuals without language being a barrier in the process.

This chapter was organized into the following sections: literature review methodology, theoretical framework (including the role of comprehensible input),

science education as a whole for K-12 students, historical perspectives, the goals of technology supported instruction, challenges for teachers in the implementation of technology supported instruction, technology and equity for ELL students, and using technology to enhance instruction,

Theoretical Framework – Krashen's Theory and the Role of Comprehensible Input

Krashen's theory was chosen as the guiding theoretical framework to address this research problem while being interwoven with the theory of cognitive constructivism. These two theories were chosen due to the applications of comprehensible input and constructing knowledge through experience. Krashen's theory can be defined as a set of five hypothesis that are used to explain the acquisition of language for second language learners. According to Krashen (2015), these hypotheses consist of the Acquisition-Learning hypothesis, the Monitor hypothesis, the Natural Order hypothesis, the Input hypothesis, and the Affective Filter hypothesis (pg. 9). The acquisition-learning hypothesis involves meaningful interaction in the target language through natural communication. According to Krashen (2015), the acquisition-learning hypothesis begins with an inductive approach which students acquire the language through student centered learning. Student centered learning is defined by Krashen as instruction which allows the student to be an active participate in their own learning, with the teacher acting more as a facilitator. This is followed by a deductive approach in which the teacher fills in specific grammar rules after the student engagement, promoting fluency before function. The monitor hypothesis plays a minor role through the planning, editing, and correction of function. This process of students planning, editing, and correcting function involves the structures and rules of grammar and how words should be structured into sentences when

written or spoken. Krashen states that the natural order hypothesis focuses on correcting deviations in natural speech to account for specific grammar rules involved in the English language. The natural order hypothesis suggests that the acquisition of grammar follows a predictable order. However, Krashen states that grammar sequencing should be rejected if the goal is language acquisition. The input hypothesis involves the use of comprehensible input, or natural communicative input that is understood through any potential language barriers. This hypothesis is concerned solely with language acquisition and not grammar structure. The affective filter hypothesis involves variables such as motivation, self-confidence, anxiety, and personality traits and how they may either prevent comprehensible input from being used through mental blocks or promote acquisition. If ELL students have high motivation, high self-confidence, and are exposed to low anxiety situations, acquisition is more likely to take place.

Although each of Krashen's hypotheses focus on specific components of this process, his input and affective filter hypotheses form the basis of the theory and help to explain how people acquire a second language most effectively. According to Krashen (2015), context and our knowledge of the world around us plays an important role in ensuring that the input teachers provide is meaningful to students. He also suggests that his meaningful nature of the input helps students to understand the language directed at them. Interactive simulations, such as Gizmos, are structured to allow students to make these connections through vertical alignment of content, real word integrations, and visual representations that can be manipulated by the user. The prior knowledge that ELL students bring with them can be connected to current content in the English language through the incorporation of comprehensible input. According to Krashen (2015),

comprehensible input can be defined as “when the instructional input is understood by the student in a way that allows them to construct new knowledge from their experiences” (pg.2). Krashen’s input hypothesis involves the use of input that is meaningful and communicated in a way that supersedes potential language barriers, thus being comprehensible. Comprehensible input can include visuals, body language, demonstration, and physical objects. Krashen states that “communication is successful when the input is understood” (pg. 22). This concept of meaning before structure allows ELL students to naturally connect their prior experiences and knowledge in learning the content. This statement is further supported by Krashen when discussing how accuracy develops over time as the acquirer hears and understands more input. The importance of incorporating meaning was also noted within a study by Weiland (2017) when the author found that she had to make sure her vocabulary instruction was both creative and meaningful. Weiland (2017) states that “the research taught me that if they only learn words during direct vocabulary instruction, students will not increase their word knowledge enough to catch up to their English only peers” (p. 63).

The authentic nature of this input leads to a second part of Krashen’s theory, his affective filer hypothesis. This component involves creating learning experiences for ELL students which reduce anxiety and boredom while increasing motivation. High anxiety and boredom situations arise whenever ELL students are not adequately able to interactive with presented input due to language barriers which make it more difficult. According to Krashen (2015), “effective educators are those who are able to provide comprehensible input in low anxiety situations” (p.32). This strategy ensures that the content is presented in a way which removes potential language barriers, but also ensures

that the instruction reduces anxiety and boredom through meaningful use of the content. Thus, comprehensible input needs to be authentic, remove language barriers, and allow for the connection of prior knowledge and experiences to new learning. Interactive simulations, such as Gizmos, may help to facilitate this type of environment through their focus on all three components.

The theory of cognitive constructivism was developed by both Jean Piaget and John Dewey. John Dewey placed great emphasis on students learning through interactions with their environment. He proposed doing this within his theory of cognitive development through a “reciprocal, continuous relationship between thinking and doing” (Lutz & Huitt, 2004, p. 2). Piaget expanded upon Dewey’s idea of students learning through interactions with their environment. One aspect of Piaget’s work discussed by Lutz and Huitt was concerned with growth of knowledge and understanding and how “new information is processed by learners through the processes of assimilation and accommodation” (p. 2). While assimilation is the process in which new knowledge is incorporated into existing structures through direct life experiences, accommodation is where the learner’s mental structures must be altered with new experiences. Piaget theorized that learners actively construct new knowledge through these two processes by interacting with the world around them in natural, constructivist ways. Piaget’s theory included that “learning is a process of adjustment to environmental influences” (Mambrol, 2020, p. 3). Baker (2019) discussed how cognitive constructivism views learning as the process of constructing meaning by making sense of experiences. Cognitive constructivism allows the students to develop meaning behind their experiences, constructing new knowledge by making sense of the world through active

discovery. In order to facilitate this active discovery, educators take on the role of facilitators by “providing the necessary resources and by guiding learners as they attempt to assimilate new knowledge to old and to modify the old to accommodate the new” (Baker, 2019, p.1).

Krashen’s theory indicates that ELL students acquire language through meaningful, understandable exposure to the target language. This meaningful exposure is directly impacted by both Dewey and Piaget’s work, since it involves students constructing new knowledge through experiences. Tricomi (1986) discusses this when stating that “by concentrating on meaning, they subconsciously acquire form” (p. 60). Krashen’s theory can be viewed as branching off from the broad theory of cognitive constructivism, which emphases student centered learning through doing. Krashen’s theory implies that activities used within the classroom for ELL students need to be presented in a way that is comprehensible through means that reduce or eliminate language barriers. Since interactions with environmental stimuli involve visual or kinesthetic means of learning, language becomes less of a factor in acquiring the new knowledge. This allows the student to acquire these concepts in a way in which language barriers are not an impediment.

According to Alanazi (2016), the connection between experiences, language, and acquisition can be found in the cognitive constructivist concept that learning is an active process that involves meaningful experiences to promote constructive thinking in the acquisition of knowledge. This construction of knowledge emphasizes the importance of connecting the already existing knowledge in learner’s minds when learning new content. Krashen’s hypothesis of comprehensible input mirrors this focus by allowing ELL

students to construct new language based on experiences which allow them to naturally make these connections while minimizing language barriers in the process. This concept of making natural connections is further discussed by Alanazi (2016) when stating how this instructional approach “helps children to be guided by their curiosity instead of being involved in a large amount of teacher directed instruction” (p.3). With cognitive constructivism and its connections to Krashen’s theory of comprehensible input, this means that the teacher becomes the facilitator while the students become the center of the learning environment. Alanazi (2016) states that “providing support through scaffolding instructions while still allowing students to be driven by their curiosity is much more effective than spoon-feeding large amounts of information” (pg. 4). However, According to Krashen (2015), the importance of this input being authentic, or valuing students’ interests and building upon what they already know, to students cannot be overlooked.

Finlinson (2016) reported that teachers who incorporate meaningful activities which utilize comprehensible input through task-based activities, actively encourage a comfortable environment, and construct well-planned lessons seem to be the most successful in their language teaching. These teaching strategies promote active participation from the students which, in turn, affords them more practice to use the language in meaningful ways. Goldenberg incorporated the topic of Krashen’s theory of comprehensible input with the use of the SIOP (Sheltered Instruction Observation Protocol) model to bridge the gap between teachers and ELLs through a framework that supports content instruction. Goldenberg (2008) discussed the concept of sheltered instruction and how it assists students in developing academic English while learning grade-level material. Through sheltered instruction, students are provided extra support

by teachers including instructional techniques that make learning comprehensible to them.

Further use of Krashen's theory of comprehensible input was found in a study on integrating content and language learning effectively in a mathematics or science classroom. Short (2016) stated that the "theoretical underpinning is that language acquisition is enhanced through meaningful use and interaction. Comprehensible input is crucial when students are not proficient in the language of instruction. Teachers therefore use visuals, gestures, less complex speech, modeling, and other techniques to present key information" (p. 4240).

Finally, comprehensible input was also included in an article related to strategies for improving ELL students' understanding of content and expectations in the physical education classroom. Toscano and Rizpoulos (2013) stressed the importance of lessons which emphasize the use of strategies that make the input comprehensible in the improvement of academic, social, and emotional competence and discussed how language is more comprehensible when it is presented in a context-embedded way with additional supports such as visual and oral cues being involved. This type of input is supported by both Krashen's theory of comprehensible input and cognitive constructivism through the incorporation of instructional strategies which involve meaningful presentation of the material in a way in which potential language barriers do not impede ELL students' ability to understand and construct new knowledge through their actions.

I am using Krashen's theory of comprehensible input with connections to cognitive constructivism to conduct my research in order to further investigate how the incorporation of interactive digital simulations through the Gizmos program impact students' language acquisition. According to Diallo (2014), technology itself plays a key role by assisting educators in the creation of leaning environments were comprehensible input contributes to the lowering of ELL students' affective filter. Using cognitive constructivism and Krashen's theory as a guide will support designing instructional materials that make the concepts accessible regardless of potential language barriers and help to ensure that fluency is promoted before function.

Science education as a whole for K-12 students

Science education both nationally and regionally within the state of South Carolina has shifted to the Next Generation Science Standards (NGSS) in 2014 (NGSS Lead States, 2013). These science standards are focused around three dimensions: disciplinary core ideas, scientific and engineering practices, and cross-cutting concepts. Instead of each of these dimensions being taught in isolation, the NGSS encourage integration with multiple core concepts throughout each year. According to the South Carolina Department of Education (2021), this approach promotes teaching science through the integration of rigorous content and application which reflect how science is practiced in the real world. Although the NGSS promote a more real-world approach to teaching science throughout kindergarten to twelfth grade (K-12), national assessment data from the National Assessment of Educational Progress, or NAEP, indicates that student comprehension remains low for the concepts involved. A recent Nation's Report Card from the National Assessment of Educational Progress (NAEP) showed that the

respective proficiency rates for the fourth, eighth and twelfth grades stood at thirty-six percent, thirty-five percent, and twenty-two percent in science (U.S. Department of Education, 2019). According to the National Academies of Sciences, Engineering, and Medicine (2015) “many American students and adults still fail to grasp fundamental scientific concepts and to understand the process of scientific discovery” (p. 11). A recent report card from the South Carolina Palmetto Assessment of State Standards (SCPASS) showed the respective proficiency rates for fourth and eighth grades in the school district where this study was conducted stood at thirty-six percent and forty-two percent in science (South Carolina Department of Education, 2021). Average state scores for this same assessment were forty-four percent and forty-two percent. Fourth and sixth grade scores for ELL students, indicated as students who were limited English proficient on the state report card, stood at thirty-six percent and thirty-five percent. These data show that ELL students within the state who had limited English proficiency scored eight percentage points lower in fourth grade and seven percentage points lower in sixth grade. These data suggest that although the standards themselves have changed to promote more real-world thinking and integration of science content, that actual strategies being used in classrooms may not be aligned to best promote this new approach to teaching science. According to Harris, Sithole, & Kibirige (2017), “This approach in which engineering, technology, and applications of science are integrated and introduced at every grade level of science education is a major shift from the current approach that requires a different kind of thinking and planning by educators” (pg. 2). There is an increasing concern with the availability of needed classroom technology resources to support the implementation of these new standards. This statement is supported by a recent Nation's Report Card

from the National Assessment of Educational Progress (NAEP) which indicated that thirty percent of all fourth-grade students and forty-two percent of all eighth-grade students in the nation reported that they participated in inquiry-related activities in their science class at a frequency ranging from never to once in a while (U.S. Department of Education, 2019).

Historical Perspectives

One of the most significant changes in education for ELL students occurred when The United States Department of Education Office for Civil Rights (OCR) began enforcing Title VI of the Civil Rights Act of 1964. This Act prohibits discrimination based on race, color or national origin in programs and activities that receive federal financial assistance. Title VI has been interpreted by U. S. Federal Courts to prohibit denial of equal access to education because of a student’s limited proficiency in English. Thus, Title VI protects those students whose English language skills are limited to the point that they cannot participate in, or benefit from, regular or special education school instructional programs (U.S. Department of Education, 1964). During the late 1960s, The United States Department of Education Office for Civil Rights became aware that many school districts around the country little or no provision for the education of students who were unable to understand English. The United States Department of Education Office for Civil Rights then issued a memorandum, on May 25, 1979, to clarify Title VI requirements that school districts needed to have in place to provide equal education opportunities to English Language Learners. One of the key pieces of this memorandum stated that school districts must take affirmative steps to rectify the language deficiency of ELL students (U.S. Department of Education, 1970). This means that school districts must provide language

instruction that is meaningful by providing ELL students with both the social and academic language skills they need to succeed.

In 1974, Congress then passed the Equal Educational Opportunities Act (EEOA). This Act was designed to require school districts to establish language programs and eliminate language barriers in schools by specifying that the failure of an educational agency to take appropriate action to overcome language barriers that impedes equal participation by its students in its instructional programs was a violation of title VI of the Civil Rights Act of 1964 (U.S. Congress, 1973). In 1991, The United States Department of Education Office for Civil Rights issued a Policy Update on Schools' Obligations Toward National Origin Minority Students with Limited-English Proficiency (LEP students). This is important, since all three students involved within this study are classified as limited-English proficient. The United States Department of Education then passed the No Child Let Behind (NCLB) Act of 2001. The No Child Left Behind Act “simplified Federal support for English language instruction by combining categorical bilingual and immigrant education grants that benefited a small percentage of limited English proficient students in relatively few schools into a state formula program” (U.S. Department of Education, 2001, pg.1). The new formula facilitated the comprehensive planning by States and school districts needed to ensure implementation of programs that benefit all limited English proficient students by helping them learn English and meet the same high academic standards as other students. According to Clewell (2007), the effect of No Child Left Behind on ELL Students in K–6 education was mixed. This was clarified when stating that “by focusing attention on their educational needs, the law has resulted in the improvement of educational services to ELL students. At the same time, NCLB has resulted in undue

pressure being placed on these students due to increased and sometimes inappropriate testing (pg. 6). Furthermore, Clewell found that that No Child Left Behind “has pushed districts with high enrollments of ELL students to align ELL programs with the general curriculum and state standards” (pg. 29). However, this same push did not occur for school districts that had low enrollment of ELL students.

According to Hosni (2017), “it was recognized that NCLB's rigid requirements became increasingly impractical for schools and educators. Therefore, in 2010 educators and families called on the Obama administration to create a better law that is focused on thoroughly preparing all students for success in college and careers” (pg. 10). Every Student Succeeds Act (ESSA) was signed by President Obama on December 10, 2015. More careful consideration of ELL students was given in Every Student Succeed Act by “taking in consideration that ELL group consists of different heterogeneous subgroups such as the recently arrived ELLs or long-term ELLs (Hosni, 2017, pg. 11). This emphasized the WIDA test which identified specific subgroups of ELL students as they progressed through different levels of language proficiency. Additionally, Every Student Succeeds Act reduced the emphasis on standardized testing of ELL students by giving schools an option on when to apply ELLs assessments scores to their school rating for the first year of them being provided services. In the second year, the scores would have to show a certain amount of progress. Finally, in the third year ELL assessment scores would need to be on the same level as their grade level peers. However, according to Tolbert (2011), “this is problematic because it may take as long as seven years for these students to acquire a level of language proficiency comparable to native speakers” (pg. 66). According to Perez and Morrison (2016), this reduced emphasis on standardized testing during the first several

years is important because of "the fact that ELLs are underperforming in assessments does not mean they are less knowledgeable or less able, it solely means they are still learning English and language is posing a barrier in their performance scores" (pg. 3).

The Common Core State Standards Initiative was a joint project of the National Governors Association and the Council of Chief State School Officers. The common core state standards pursued two standards-based reforms: development of new content standards and development of new assessments (Common Core State Standards, 2010). The goal of this initiative was to raise and equalize expectations for all students, with an explicit goal to close achievement gaps. However, according to Bleiberg (2021), "the common core content standards were more rigorous than the typical content standards used prior to their implementation" (2). According to Maarouf (2019), "Common Core State Standards have widened the academic gap between ELL students and their English-speaking peers" (pg. 92). Science curriculum within the state of South Carolina is based on the Next Generation Science Standards (NGSS), which are similar in scope to the common core standards as "the convergence of the NGSS and the CCSS around the productive use of language in authentic contexts represents a major shift in the role of language in all areas of instruction" (Tolbert, 2014, pg. 66). According to Maarouf (2019), "One of the greatest challenges hindering the ability of ELL students to perform well in content subjects at the appropriate grade level is perhaps the lack of sufficient vocabulary development" (pg. 91).

Educators of ELL students have a twofold focus when designing learning experiences for them in the classroom, language acquisition and content comprehension. Hernández (2003) expand upon this when she discussed how instruction for ELL students must include a focus on content, language, and general skills goals. Typically, ELL

students are stymied in their content comprehension due to language barriers, especially in core content areas such as science where they may not have prior exposure or use of the domain specific vocabulary. MacGowan (1991) states the following problems that ELL students face in achieving their educational goals: “lack of fluency or adequate control over the language, including inadequate vocabularies; general lack of knowledge and the consequent inability to write effective pieces; and errors in grammar and the mechanics of writing, despite the fact that most ESL students have had years of instruction in both” (p. 1). MacGowan (1991) further explores the concept of comprehensible input through Krashen’s theory by stating that “the input provided to learners is comprehensible, interesting and/or relevant, not grammatically sequenced, and provided in abundant quantity” (p. 75). The whole language approach discussed by the author stressed the importance of promoting fluency first over grammatical correctness. In this approach, MacGowan (1991) placed emphasis on skills rather than grammar, memorization, and repetition. This type of approach promotes Krashen’s theory of comprehensible input through the focus on fluency rather than structure first. Language is acquired in a holistic manner through meaningful learning experiences and interactions with the content.

Gomez and Madda (2005) discussed the importance of differentiating the middle level science curriculum in ways that would make acquiring the content more accessible and equitable for ELL students. The authors state that “the best practices literature suggests that teacher-planned activities should get students actively involved in listening to the language and in using it in meaningful ways (Gomez and Madda, 2005, p. 43). Gomez and Madda (2005) stressed the importance of paying attention to students’ use of

content specific vocabulary in both natural and task-driven settings. This means providing ELL students with learning experiences that involve the removal of language barriers and paying closer attention to the "mode of interaction when the challenge is conceptual versus vocabulary knowledge" (Gomez and Madda, 2005, p. 45).

Marsh (2018) discussed the history and importance of differentiating instruction for ELL students. The author mentioned the 1974 Supreme Court case, Lau v. Nichols, that decided that the rights of ELL students are violated when a school takes no steps to help them acquire the language of instruction. According to Marsh, the United States Office of Civil Rights used this decision to mandate "transitional bilingual education, or teaching students in their home language as a bridge to English language learning and content instruction" (pg. 5). This decision informed what are known as the Lau Remedies, a set of federal policy guidelines requiring school districts to provide appropriate programs to ELLs to ensure that classroom instructions is meaningful and accessible to them. According to the author, there has been a decades-long debate since 1974 about how long ELLs should receive services and what theories of language learning should support guiding principles in administering them. According to Marsh (2018) Krashen's theory involving the role of comprehensible input has contributed "to a classroom environment that enhances the use of comprehensible input and has been found to foster engagement and facilitate access to the English language (pg. 13).

Goals of Technology Supported Instruction

The goals of technology supported instruction include making the content more accessible, enhancing the learning experience, and improving communication skills.

Cutter (2015) states that technology supported instruction can assist with the integration of "authentic learning opportunities; helps students develop language and literacy skills as they make connections among text, images, video, sound and animation; and encourages students to construct meaning and to make connections to their prior knowledge" (p. 6). Furthermore, Cutter (2015) discussed the significant impact of computer-based web programs and how learning tasks constructed with them can simulate real, authentic language use, which consequently ends in meaningful learning. Short (2016) describes a program of research that developed from the SIOP Model in one study and then tested its efficacy and refined its professional development design in subsequent studies in a number of different contexts over 15 years. The SIOP Model is an approach used widely in the United States for teaching subjects like mathematics and science to students learning a new language. Teachers integrate visuals and modeling techniques that make the concepts accessible with techniques that develop the students' skills in the academic language of the specific subjects. Results from Short's study revealed that students with teachers who were trained in the SIOP Model and implemented it with fidelity performed better on assessments of academic language than students with teachers who were not trained in the model.

Diallo (2014) applies the role of comprehensible input from Krashen into the impact that computer-based web programs can have on ELL students' achievement when stating that "one tool that will help struggling ELLs is technology-based differentiated instruction, defined as scaffolding strategies that include but are not limited to digital tools that provides exciting, hands-on and innovative comprehensive input" (p. 13). This kind of technology rich environment also plays into Krashen's affective filter due to the

fact that “technology-based teaching strategies offer comprehensive input in a low affective filter and stress-free environment. Most users are therefore excited when offered to learn using technology tools, and this excitement motivates them to learn” (Diallo, 2014, p. 14).

Toscano and Rizopoulos (2013) discussed how the use of interactive technology for middle school ELL students can help to promote an engaging, differentiated learning environment that reinforces critical skills learned in class. This level of differentiation may help to enhance the learning experience through interactions with the content which are engaging, meaningful, and that reduce language barriers. Toscano and Rizopoulos (2013) described how a variety of technology supported devices and applications were able to help provide modified student feedback that reinforced content area vocabulary within the educator’s fitness lessons. This modified feedback present within the interactive technology connects with Krashen’s theory of comprehensible input through meaningful interactions with the content presented in a way in which language barriers do not impede ELL students’ ability to make connections and construct new knowledge. Fox (2014) included a limitation within her study indicating that many students may struggle to use technology effectively within the classroom environment. Fox indicating this when stating that “although we are in the twenty-first century, not all of the students are digital natives therefore requiring an increased level of teacher guidance when using technology to help improve literacy skills” (pg. 39). However, Crum (2017) concluded that “technology-supported instruction makes a significant difference in content area comprehension” (pg. 95). Both authors stress the importance of the teacher being present when technology supported instruction is being utilized.

Along with making the content more accessible and enhancing the learning experience, technology supported instruction may aid in the challenge of improving ELL students' communication skills in terms of demonstrating what they know. Abdul (2018) discussed how real-life tasks such as role plays, dramas, and simulations could be utilized within the classroom for students to cultivate their competence through a variety of situations which involved meaningful spoken interactions with the content. This improvement in communication skills would assist in finding formative ways to assess ELL students' comprehension of the content that does not necessarily involve a high stakes summative test. In addition, it supports a holistic, whole language approach to teaching and assessing science content that is more equitable to the needs of ELL learners.

Challenges for Teachers in the Implementation of Technology Supported Instruction

The inequitable access to technology resources across many school districts presents a problem in itself for effectively implementing technology supported instruction. In addition, professional development and time is needed for educators to properly understand the technology and programs that are available to them. Limitations to the implementation of technology supported instruction include the accessibility of devices and the lack of time for preparation and understanding the available technology and programs. Cutter (2015) addresses how it is essential for teachers to be familiar with various applications and websites to best support the planning and instructional use of them with students. In addition to the teacher being familiar with the technology, ELL students need to be provided with ample opportunities to interact with the programs. Fox

(2013) discussed how not all students are digital natives and many require an increased level of teacher guidance may be required to help improve digital literacy skills. The address the potential issue of students not being digital natives before the study is conducted, guided and independent practice sessions were used involving the devices and program to ensure that the ELL students involved have ample opportunities to interact with them and become familiar with their use. Since I have been using the technology and Gizmos program for approximately five years already, I am familiar with both in terms of preparation and instructional use.

This inconsistent availability of technology use was also noted by Ramirez (2012) and Smith (2013) as limitations within their studies. Ramirez (2012) discussed how teachers recognized the inconsistent use of visual aids on a regular basis due to the lack of time and unavailability of technological devices. Smith (2013) also noted in the limitations of her study that students completed their gizmos as computers were available and as a result, not all participants completed the same gizmo at the same time. To pre-plan for this potential problem in inconsistent availability of use, I acquired a class set of devices that were consistently available within my classroom during the duration of my study.

Technology and Equity for ELL Students

Technology supported instruction allows educators to better differentiate for ELL learners through the incorporating of more comprehensible input, meaningful learning experiences, and the reduction of language barriers through a fluency first approach. In addition, it allows educators to focus on a more holistic, whole language approach when

assessing that allows ELL students multiple ways of demonstrating their comprehension both textually and orally. MacGowan (1991) found that this fluency first type of approach resulted in students showing “more growth in the affective domain, specifically more confidence, better ability to work with groups, and more tolerance for divergent views” (p. 83).

Ramirez (2012) discussed how new technologies have created new possibilities to incorporate visual aids within the classroom but are yet to be fully exploited in a systemic matter. Programs that incorporate interactive visual aids have the ability to not only remove language barriers for ELL students, but also create learning experiences which are meaningful and engaging. Studies related to their impacts on ELL achievement in science have the possible outcome of improving professional development programs for core content teachers on effective strategies to use with their ELL learners and school districts in terms of what programs to provide funding for in core content areas that have proven results for assisting in differentiating the content for middle level ELL science learners.

Stairs-Davenport and Skotarczak (2018) discuss the role that technology plays in providing comprehensible input for ELL students in providing equity through processes which assist in scaffolding the content to simplify terms in ways that they can understand. This modification of the presentation of content using technology may involve applications which include photos, illustrations, diagrams, videos, auditory components, and differentiation of content which promote an engaging, student-centered process that helps to reduce the ELL students’ affective filter and increase the amount of comprehensible input being provided during instruction. Stairs-Davenport and

Skotarczak (2018) go onto to describe how learners who are comfortable and have a positive attitude toward learning the language and content have their affective filters set low, allowing unfettered access to comprehensible input. According to Baker (2019), this shift from teacher centered to student centered learning also promotes a cognitive constructivist approach to learning, since the ELL students are interacting with the content in ways which involves them constructing meaning through experiences which utilize active discovery.

Irby et al. (2018) describe how the implementation of technology within middle school ELL students in science can help to provide equity in terms of differentiating the curriculum. The authors discussed how integrating technology can help to promote active and effective knowledge acquisition through meaningful learning experiences and supportive scaffolds which include graphics and animation. However, the authors noted one potential limitation based on a case study involving seventh and eighth grade ELL students in an urban school district using interactive simulations. Irbi et al. (2018) reported that ELL students were less likely to become engaged in computer simulations unless student to student collaboration was included within instruction. This is significant for my own study since it involves incorporating interactive simulations on an individual basis and not a collaborative one.

Using Technology to Enhance Instruction

Banditvilai (2016) investigated the use of blended learning, which is a combination of in person instruction and technology enhanced instruction, on students' language skills and autonomy at the university level. This mixed method case study

focused on English acquisition skills in listening, speaking, reading, and writing. The achievements and attitudes of sixty students involved in the study were compared between a control group and experimental group to measure the potential of available technology to develop language skills and learner autonomy. Banditvilai (2016) reported findings from this study that showed that online practice is directly beneficial to enhance the four language learning skills as well as autonomous learning and learner motivation. This computer enhanced aspect changed the roles of teacher and student within the instructional environment from a teacher centered environment to a student-centered environment.

Pritchard and O'Hara (2009) also investigated the impact of technology enhanced instruction on ELL students' vocabulary development within the science classroom. This mixed method study involved fourteen ELL students within a middle school science classroom who were randomly selected from the larger population present at the school. The author investigated the impact that hypermedia projects had on content specific language acquisition and use. This type of technology enhanced instruction incorporated meaningful, task-based activities that ELL students navigated through at their own pace. Students were able to choose their own words and images to represent the content, make connections to prior knowledge, demonstrate their comprehension. Pritchard and O'Hara (2009) reported results which indicated that hypermedia authoring had a positive impact on students" understanding of grade level science concepts. The authors also reported that these technology-enhanced projects had a positive impact on student engagement and attitudes toward the learning process. This study involves the application of Krashen's theory of comprehensible input through technology enhanced instruction which

incorporated a low anxiety process that reduced the impact of potential language barriers in acquiring new knowledge in the subject area.

Keengwe and Hussein (2014) explored the impact of using computer assisted instruction to enhance achievement of English language learners. This mixed method study involved ELL students in both reading and mathematics and included technology enhanced curriculum materials which were meaningful, encouraged teamwork, and provided opportunities for scaffolded practice time. Kaangwe and Hussein (2014) reported results which suggested that students who used computer assisted program had a greater chance of closing achievement gaps in reading and math through higher state assessment scores gained in these two areas. This is important since my own study involves a computer assisted program being used to close achievement gaps between ELL students and their grade level peers.

Park (1994) further explored the use of technology enhanced instruction by investigating the impact of using interactive multimedia in the classroom through the facilitation of independent and responsible learning. This qualitative case study was conducted over the course of eight weeks using an interactive multimedia program called ELLIS (English Language Learning & Instruction System). The students can have input from the program by selecting and listening to a dialogue, then have various interactional modifications through provided exchanges. The students can make their own decisions to select different types of modifications, then the program can give modified input from the students' selections for the purpose of content learning. The author reported in the results that "students who worked on ELLIS individually could use a high level of learning

strategies, such as evaluating, self-evaluating, problem solving, and experienced their own independent, responsible, and meaningful learning" (Park, 1994, p. 177).

This role of modified input through interactive technology resources was also present in a study by Gosnell (2013) who explored the effective use of the technology driven program Imagine Learning on instruction for ELL students. This quantitative case study was conducted with two groups of students to discover whether or not interactive technological resources are an effective use in English Language Learner classrooms as a means for instruction. One group of students was studied based on their scores without having any technology in the classroom from a school that does not use the program. The other group of students was monitored based on scores after having gone through the interactive technology program. The author reported results indicating that students who "used the program with validity have higher scores and are closer to proficiency than those students that were not exposed to this program. Therefore, the overall gains of students using this program are indeed effective and impactful for students who are learning the English language" (Gosnell, 2013, p. 16).

Technology was also a focus for Crum (2017) who investigated the influence of technology on English language learners' vocabulary, reading, and comprehension. This comparative case study's purpose was to assess the vocabulary and reading comprehension outcomes of ELLs in the content area of 5th grade social studies when taught using technology-supported versus traditional textbook instruction. Fifty-five ELL students at an elementary school from preexisting classroom groups were taught using technology-supported or traditional textbook instruction. Instructional groups' vocabulary test scores were them compared using a pretest and posttest. The author's "results

revealed that 5th grade ELL students in the technology-supported instruction group scored significantly higher on the social studies vocabulary posttest as compared to the traditional textbook instruction group" (Crum, 2017, p. 4).

The impact of technology supported instruction was also studied by Head (2014) who investigated the use of computer simulations as an instructional approach for high school physics English language learners. This mixed methods study involved a total of 44 ELL students who were randomly assigned to two treatment groups (computer simulations group and traditional laboratory group). Student journal entries and videotaped speech transcriptions were analyzed and transformed into quantitative frequencies and percentages. The author's results "confirmed simulations assisted ELLs in grasping concepts but did not support simulations as encouraging conceptual conversation. Computer simulations can visually demonstrate abstract science concepts to ELLs" (Head, 2014, p. 3). In addition, the author reported that the average percent gain from a pre-test to post-test "for the hands-on laboratory investigations was 20% below the computer simulations participants (Head, 2014, p. 167).

The study of interactive simulations was also present in a study by Ranalli (2008) who investigated the impact of a computer simulation-based game on students' perceptions and its potential as a language-learning tool. This mixed methods study involved a convenience sample of nine intermediate-level ELL learners enrolled at a major Midwestern research university. To assess vocabulary acquisition, descriptive statistics were calculated for the pre and post test scores, and then a paired-samples t-test was conducted to compare means. The author "found statistically significant improvements in vocabulary knowledge, as well as a generally positive reaction to the

modifications among students” (Ranalli, 2008, p. 1). The author further reported that “this study has provided further evidence that commercially produced computer simulation games can, with theoretical guidance, be adapted for use by ESL students” (Ranalli, 2008, p. 15).

The most closely aligned study to my own involving interactive simulations was conducted by Smith (2013) who investigated the use of Explore Learning's science simulations in improving student achievement. This quantitative study explored the use of online, computer simulations in science over a six-month period as an instructional tool. Over the course of five to six months, fifty fifth grade science students completed a series of eighteen Explore Learning activities, known as Gizmos. Components of the study included teacher observations, teacher-guided and independent simulations, and students completing short quizzes after each gizmo activity. Data was analyzed and triangulated through student responses, tests/benchmarks, and a final written report. The author reported results that students became more engaged in science and that the results “validated that web-based simulations used in conjunction with other instructional methodologies made enough of a difference in closing achievement gaps among certain at-risk populations to justify continued use of online simulations and warrant further research on Gizmo’s efficacy in reaching struggling learners” (Smith, 2013, p. 1).

Summary

The goals of technology supported instruction include making the content more accessible, enhancing the learning experience, and improving communication skills. These goals may be met with more targeted differentiated methods that technology

supported instruction can provide by enhancing the learning experience and promoting a fluency first approach. The relevant research and literature used share similar conclusions that educators need to focus on methods of differentiation for ELL students that make the content accessible through the removal of language barriers. Removing these language barriers includes improving the use of comprehensible input through technology enhanced instruction. According to the related research, programs in this technology enhanced instruction include interactive multimedia such as Imagine Learning and ELLIS, game-based learning experiences such as the SIMS, and interactive simulations such as Gizmos.

Krashen's Theory and the role of comprehensible input was evident in many of the articles and studies and tied into how programs such as Gizmos may be used to provide more meaning through the modification of input that ELL students are presented with during instruction. Since my present action research study focuses on the impact of using interactive simulations with Gizmos for middle level science ELL learners, these studies support the need for additional research in this area. Although there are challenges to teachers in the implementation of technology supported instruction, results from the provided studies show the need in doing so. These results show positive outcomes to ELL students content comprehension and can help to construct more equitable lessons for this diverse group of learners.

Studies from Banditvilai (2016), Pritchard, and O'Hare (2009) connect with my own due to the technology enhanced aspect of curriculum presentation through processes which promote more meaningful interactions with the content. Each of their studies involves the use of technology to promote a visual and meaningful learning experience to

make the content more accessible through comprehensible input. In addition, Keengwe and Hussein's study connects with my own through the incorporation of technology enhanced program which provides meaningful interactions with the content using visual aids to support the reduction of potential language barriers. Park's article connects with my own since it deals with the importance of meaningful learning and input. Gosnell, Crum, Head, and Ranalli's studies further expand upon the use of technology by involving how technology plays a role in modifying input to make it more comprehensible through the use of interactive simulations as a potential tool for supporting language acquisition. Finally, Smith's study connects with my own since it involves the same interactive simulation program that I plan to use, Gizmos, and how it impacts student achievement. The visual nature of Gizmos aligns with cognitive constructivism developed by Piaget and Dewey by allowing students to construct new knowledge through experiences. The use of Gizmos also aligns with Krashen's theory through meaningful, understandable exposure to the target language.

Chapter 3

Methodology

According to Lesha (2014), “Action research is a spiral process that includes problem investigation, taking action & fact-finding about the result of action. It enables a teacher to adopt/craft most appropriate strategy within its own teaching environment (pg. 379). This description of action research is supported by Efron and Ravid (2013) when stating that “action research is usually defined as an inquiry conducted by educators in their own settings in order to advance their practice and improve their students’ learning (pg. 2). As opposed to using generalized principles presented through traditional research that may or may not apply to a specific population of learners, action research allows for the specialization of teaching strategies to meet the needs of a specific group of students. Since ELL students are often impeded by language barriers in their acquisition of content, qualitative action research is being used to focus on collecting multiple types of descriptive data for a more holistic approach to understanding the impact of the intervention. A holistic approach “involves reporting multiple perspectives, identifying the many factors involved in a situation, and generally sketching the larger picture that emerges” (Creswell, 2014, p.235).

Understanding will be defined as verbal and written comprehension of the concept in their own words followed by the association of content-specific terminology with the concept. Verbal and written comprehension were chosen together in order to

provide a comprehensive view on the relationship between using interactive simulations with Gizmos and ELL students' ability to acquire the content. According to Ültanır (2012) comprehension is defined as students creating or "constructing their own new understandings or knowledge through the interaction of what they already believe and the ideas, events, and activities with which they come into contact" (pg. 1). This definition of comprehension is aligned with the theory of constructivism in which learners are encouraged to construct their own knowledge of the world through experiences. This particular type of intervention was chosen due to the programs ability to present science in a way that is interactive, reduces verbal and textual language barriers, and connects to prior knowledge and real-world experiences.

Rationale for the Research Methodology

A qualitative case study using action research was chosen to provide structure through the methodological design of the study. According to Efron and Ravid (2013), action research is defined as "an inquiry conducted by educators in their own settings to advance their practice and improve their students' learning (pg. 2). For educators, this involves taking a systematic approach to analyzing their own teaching practices in order to improve their students' learning. A case study was right for my study since it "aims to understand a particular phenomenon by selecting a particular example of that phenomenon as the focus for the study" (Efron and Ravid, 2013, pg. 41). The selected phenomenon, or intervention, being studied is an interactive simulation program known as Gizmos. The specific teaching practices being analyzed within this study are the types of input provided to ELL students. Interactive simulations are being incorporated as an

intervention to understand how their integration may impact ELL student comprehension of the content within a middle level science classroom.

Intervention

This study involved the integration of an interactive simulation program known as Gizmos into instruction. Regular class sessions before this intervention include direct instruction, collaborative discussion, hands-on labs, and computer assisted remediation and extension through test prep programs. Gizmos aligns with the science content outlined within the Next Generation Science Standards by focusing on meaningful integration of vocabulary through simulation-based activities. These simulations take the concept of hands-on labs a step further, since they allow students to explore abstract concepts in more concrete ways through visualization and manipulation of scientific phenomenon. These interactive simulations allow students to manipulate scientific concepts through an inquiry-based approach. The Gizmos program also provides handouts which align with each interactive simulation which may be structured into full lessons including activators, guided instruction, and independent practice. Gizmos was used to facilitate the teaching of content daily for two weeks. Students used two separate Gizmos during this time, with each one taking approximately two days to complete. Only the supplied handouts were used which are provided by the program.

I observed and documented ELL students' nonverbal behaviors, gestures, and body language as they used the Gizmos to determine if the input was comprehensive and meaningful. Questions from the provided handouts were asked both orally and textually to determine the level of student comprehension throughout the intervention. These

handouts include instructions on how to navigate through different parts of the interactive gizmo simulation. Additionally, there were questions embedded which align with the content and facilitate students moving through the simulation in a way which supports them beginning with describing the content in their own words before eventually connecting the concepts with the domain specific vocabulary involved. Since the handouts were uploaded in a digital format for participants to complete and submit, all three students involved within the study also had the option for the text to be read aloud to them. The questions asked were open ended to allow students a variety of ways to communicate their understanding of the content.

Research Setting, Sampling Plan and Participants:

The specific setting for this action research project involved three general education sixth grade science classes that I directly teach. Each of the classes includes approximately twenty-five students in all, with one ELL student per class. This study involved three ELL students with varying WIDA proficiency levels between one and four. These proficiency levels were chosen since students within them still are classified as having limited English proficiency (LEP) and struggle with language barriers, based on the results of their individual WIDA assessment scores. The participants were chosen through purposeful sampling to select specific students with WIDA proficiency levels between one and four that I directly teach in sixth grade classes. “Since generalization in a statistical sense is not a goal of qualitative research, probabilistic sampling is not necessary or even justifiable in qualitative research” (Merrian & Tisdell, 2016, p. 96). Since these three ELL students were the only ones in sixth grade with WIDA proficiency levels between one and four, the sample size of three participants was chosen.

Data Collection Methods

The first data source included semi-structured observations collected daily during instruction. This data source was chosen due observations "providing a powerful insight into the authentic life of schools and classrooms" (Efron & Ravid, 2013, p.86) through activities, people, and the physical environment. These observations were semi structured by focusing on nonverbal behaviors, gestures, and body language of ELL students as they use the Gizmos program daily. This helped to determine the impact Gizmos may have on providing comprehensible input and an increased affective filer. Descriptive notes were taken to record what is happening without inferring feelings or responses. Thick descriptions were constructed from these notes to create a narrative that brings the setting to life by "allowing the reader to have the feeling of being there" (Efron & Ravid, 2013, p.88).

The second data source included semi-structured interviews collected daily during instruction. These interviews were naturally incorporated into the flow of instruction to help support issues of ethics within the study. The questions were open ended and prepared prior to the interview to focus on understanding how the intervention is impacting ELL students' verbal comprehension of the content. In addition, follow-up interviews were conducted to "probe further to encourage the participant to extend or deepen his or her responses" (Efron & Ravid, 2013, p.98). The follow up interviews were conducted four weeks after students had initially completed the two Gizmos simulations and were focused on long term comprehension of the content. These interviews helped me to dig deeper into ELL students' experiences with Gizmos as a type of comprehensible input and the impact that its use has on their verbal comprehension of

science content. The following are the semi-structed and follow up interview questions asked to students.

Table 3.1: Semi-Structured Interview from Convection Cells Gizmo

Main Questions	Clarifying Questions
1. What do you notice about how the drops of food coloring in the heated beaker move?	2. Why do you think that the drops of food coloring move that way?
3. Based on what you did in activity A, can you tell me what convection is?	4. Why do you think that convection happens?
5. Based on what you did in activity C, can you tell me how convection affects either the oceans, the coast, or the atmosphere?	6. Why do you think that convection affects it (the ocean, the coast, or the atmosphere) in that way?

Table 3.2: Follow-Up Interview from Convection Cells Gizmo

Follow-Up Questions
1. What is this gizmo showing? Tell me what you see happening? 2. How does this gizmo help you to understand heat transfer by convection? 3. The bubbles show how heat is moving. Why are some bubbles rising while other bubbles are sinking?

Table 3.3: Semi-Structured Interview from Hurricane Motion Gizmo

Main Questions	**Clarifying Questions**
1. What do you notice about a weather station when a hurricane is getting close to it?	2. Why do you think that the air pressure changes that way?
3. What happens to the hurricane after it begins moving over land?	4. Why do you think that the hurricane changes that way?

Table 3.4: Follow-Up Interview from Hurricane Motion Gizmo

Follow-Up Questions
1. What is this gizmo showing? Tell me what you see happening? 2. How does this gizmo help you to understand hurricane motion? 3. When does the hurricane weaken and why does it weaken?

The third data source included student artifacts through multiple work samples from daily lessons. These artifacts consisted of Gizmo handouts that are provided with the digital simulations. These handouts include three distinct sections: Prior knowledge, Gizmo warm-up, and activity. Since the Gizmo warm up is done together as a class to model how each digital simulation works, I analyzed ELL students' written responses for their prior knowledge and activity sections. All questions on both sections are open ended and helped me to better understand the impact of the intervention on ELL students' written comprehension of the content. The data collection from these artifacts helped to

"corroborate, expand, or challenge what was gathered" (Efron & Ravid, 2013, p.122) through the other two data collection tools. The following figure outlines the timeline involved with my study:

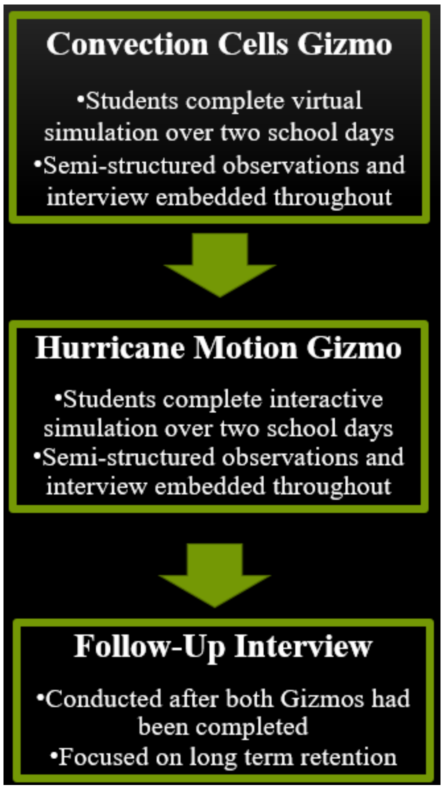

Figure 3.1: Timeline of Study

Data Analysis Methods

All data was brought together and reviewed for relevant themes that emerged, with these themes narrowing as the data was constantly compared to each of the two research questions. Finally, conclusions to each research question were drawn from the data corresponding to each of the two themes identified within the coded data. The method of data analysis used is supported by Merrian & Tisdell (2016) when stating that "to begin the more intensive phase of data analysis in a case study, all the information

about the case should be brought together. All this material needs to be organized in some fashion so that data are easily retrievable" (p. 233). Emergent coding was used to organize and analyze the collected data. Emergent coding involves "reviewing all of the data, making sense of it, and organizing it into categories or themes that cut across all of the data sources" (Creswell, 2014, p. 234). This coding began with short words or phrases written next to each data source that capture relevant themes. An inductive and comparative approach using the constant comparative method was used to further analyze these categories to eventually construct conclusions based on the findings. This process "involves moving back and forth between concrete bits of data and abstract concepts, between inductive and deductive reasoning, between description and interpretation. These meanings or understandings or insights constitute the findings of a study" (Merrian & Tisdell, 2016, p. 202). This helped me to "check whether categories derived from earlier data hold up" (Merrian & Tisdell, 2016, p. 210) when analyzing subsequent data. The first part of this process was to sort and organize excerpts of raw data into groups according to attributes and organize those themes in a structured way. The data organized included both semi-structured interview responses from participants and written responses from participants. Each of these excerpts of raw data was then compared to how applicable it was to each theme. Integrated themes and their properties were constructed based on the research questions to identify any connections with the participants' responses. The first theme was structured around participants providing a correct description of scientific concepts in their own words while using the Gizmos program. The second theme was structured around participants use of content specific vocabulary when describing concepts. If a participant's statement that was challenging to

the definition of a theme was encountered, it initiated a process of reflection and comparison with other parts of the data. Throughout data collection, the constant comparative method was a continual process to ensure that all participants' written and spoken answers were appropriately analyzed for connections to the research questions. The following figure outlines the data analysis process involved:

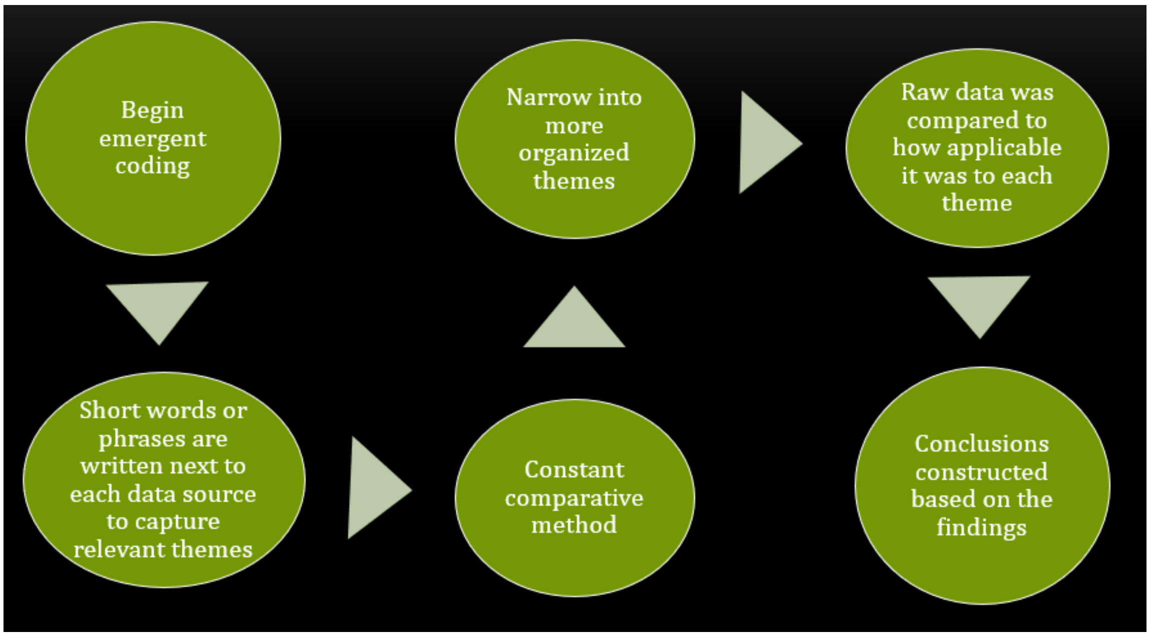

Figure 3.2: Data Analysis Process

Since my research design includes a specific program as an intervention, it involves a specific case that was used to collect and analyze data upon to determine its effectiveness on English Language learner's comprehension of the science content. "A case study is an intensive, holistic description and analysis of a single, bounded unit. Conveying an understanding of the case is the paramount consideration in analyzing the data" (Merrian & Tisdell, 2016, p. 232). This specific case involves the use of interactive simulations with Gizmos and how it impacts ELL students' in demonstrating their

comprehension of science content. The emerging themes that were constructed from the data also crossed over to action research methodology involved since “the focus in the analysis is on the unfolding of the findings in stages and phases over time” (Merrian & Tisdell, 2016, p. 235). Once these categories emerge from the collected data, analysis continued until the point of saturation. According to Merrian and Tisdell (2016), saturation “occurs when continued data collection produces no new information or insights into the phenomenon you are studying” (p. 199).

Multiple methods of data collection and multiple theories are included within the conceptual and theoretical frameworks of the study “to confirm emerging findings” (Merrian & Tisdell, 2016, p. 244). The three methods of data collection were chosen in order to provide multiple sources and perspective in understanding the impact of the intervention on ELL student comprehension of the content. This dataset is comprised of three sources of data including observations, interviews, and documents. Together, they represented a triangulated set of data for the research question, thus ensuring rigor and quality of the study. “Triangulation using multiple sources of data means comparing and cross-checking data collected through observations at different times or in different places, or interview data collected from people with different perspectives” (Merrian & Tisdell, 2016, p. 245). Internal validity is also ensured through the analysis of data until the point of saturation. This is supported by Merrian and Tisdell (2016) when stating that “the best rule of thumb is that the data and emerging findings must feel saturated.

Through action research, educators can address individualized concerns that come up through their work and use data to make meaningful solutions and changes to their practice. As long as the educator responsibly collects and interprets the data to make

meaningful changes in their environment, that action research maintains its validity and usefulness. The findings of action research do not necessarily need to be duplicatable since the focus of this type of research is to make positive changes within specific settings.

Positionality

The concept of positionality requires me to define my role within this process as a researcher in order to provide validity to my findings. This requires me to ask “Who am I in relation to my participants and my setting?” (Herr & Anderson, 2015, p. 37). Since this study involves my own classroom and a potential change to my instructional practices in designing and/or organizing assessments, I am an insider. Key stakeholders involved in this study include my ELL students who would benefit from a type of curriculum input that is more comprehensible and other teachers who would benefit from the strategies that teach the same students, since the level one to four ELL students are struggling in multiple academic subject areas.

In order to conduct this study, I needed to better understand the position my students have with the current type of curriculum input and what background they may have on the usage of the purposed curriculum input. Since best practices within our school district for science education involve assessment of the content based on application, this intervention would not result in a modification of the curriculum due to the fact that vocabulary is not meant to be assessed independently. This intervention would simply be a new way of presenting the content in a way that possibly reduces language barriers between the students’ prior knowledge and current acquisition.

Since I have not had many opportunities to work with ELL students extensively in the past, my experience in this area of application is limited. I typically have one ELL level one student per year, two to three level two students, and five to seven level three students. In addition, my background is in middle level science and social studies and not English language arts. However, my experience while obtaining my literacy endorsement highlighted the importance of developing appropriate strategies that would meet the needs of diverse groups of students. I have also dedicated much of my time during the beginning of this study to focus on reading and analyzing literature dealing with literacy strategies and how ELL students acquire language.

In addition to my personal goal in becoming better acquainted in how ELL students acquire language, my expanded role within the school district provides me with the necessary scope to incorporate my eventual findings into the existing curriculum structure. As a member of the curriculum writing team for sixth grade science within the school district, I would have the opportunity to better develop strategies that could be shared in the best interest of our local ELL population. My philosophy of education has been one of constructivism, in which “knowledge is socially constructed by learners who convey their meaning making to others” (Singh, S. and Yaduvanshi, S. 2015). This learning by doing approach has become more refined to include specifics related to Krashen’s theory of language acquisition with second language learners.

Chapter 4

Findings

The purpose of this action research study was to determine how a particular technology program, Gizmos, would impact ELL students in demonstrating their verbal and written comprehension of science content. Gizmos were used to incorporate interactive simulations for each topic taught in the middle level science curriculum. The visual nature of simulations was proposed to help reduce the language barrier between connecting prior knowledge to new learning by allowing the student to first comprehend the concept in their own way. Cognitive constructivism and Krashen's theory were both incorporated within the theoretical framework, since both work in tangent to provide theoretical support to the idea of students learning through doing. The following research questions informed this study: (a) How does the use of digital simulations provide opportunities for English Language Learners to develop understanding of content-specific vocabulary in middle school science? (b) What impact, if any, does a digital simulation game have on ELL learner ability to understand science at a proficient level (on a level with their peers of similar age/grade). This proficient level was determined based on the learning objective outlined at the beginning of each Gizmo. These learning objectives outlined the expected understanding and explanations that I wanted to see from each Gizmo experience.

A qualitative case study using action research was chosen to provide structure through the methodological design of the study. Two interactive simulations were

incorporated as an intervention to understand how their integration may impact the comprehension of three ELL students within a middle level science classroom. Semi-structured interviews were conducted with participants while each was using the interactive simulations to determine the impact of the gizmo on their comprehension. Participants also completed a handout which included content-specific vocabulary involved within the gizmo. Observations were recorded using thick descriptions to detail participant's use of each interactive simulation in answering the questions.

Participants of this study included three sixth grade students within three different general education science classes. All three participants were twelve years old; two were female, while one was male. All three participants were classified as having limited English proficiency, or LEP, according to their WIDA Access test scores. Two of the participant's primary language was Spanish, while one was Mandarin Chinese. For reporting purposes, and to protect participants' identities, each participant was assigned a pseudonym. The following table outlines each student's overall WIDA score and language of origin.

Table 4.1: Participant Characteristics

	Overall WIDA Score	Language of Origin
Student 1	3.4	Spanish
Student 2	2.8	Mandarin Chinese
Student 3	4.8	Spanish

Student 1 is a twelve-year-old female with a WIDA level of 3.4 whose primary language spoken is Spanish. Having a WIDA level of 3.4 means that they are considered developing. This level of language acquisition means that Student 1 knows and uses social English and some specific academic language with visual support. Student 2 is a twelve-year-old female with a WIDA level of 2.8 whose primary language spoken is Mandarin Chinese. Having a WIDA level of 2.8 means that they are considered Emerging. This level of language acquisition means that Student 1 knows and uses some social English and general academic language with visual support. Student 3 is a twelve-year-old male with a WIDA level of 4.8 whose primary language spoken is Spanish. Having a WIDA level of 4.8 means that they are considered expanding. This level of language acquisition means that Student 3 knows and uses social English and some technical academic language.

Results of Convection Cells Gizmo

I conducted the first interactive simulation gizmo with students about convection cells. The learning objective of this gizmo was to use models to describe the process of convection and how it impacts real world phenomenon. To demonstrate grade-level comprehension on this gizmo, students needed to be able to use the gizmo to describe what happens during the process of convection. This understanding involved being able to describe that convection is the process in which heat transfers within a fluid, that convection results from differences in temperature and density, and that hot fluids rise while cold fluids sink. The gizmo allowed students to observe a drop of food coloring placed in a beaker of water. Students were able to turn on a heater at the bottom of the

beaker of water. The drop of food coloring then moved in specific directions based on whether it was heated or cooled.

During the first gizmo over convection cells, all three students were seen beginning with the prior knowledge section of the handout by answering the prior knowledge questions. Each participate took approximately two minutes to look over the provided diagram before using the interactive Gizmo and asked a question which could be answered based on prior knowledge and experience. The prior knowledge section was completed individual by each student and then checked by the teacher to determine what prior knowledge or connections each student had with the topic. Student 1 and Student 2 were able to connect prior knowledge with the current concept by recording that soup is hot when it rises and sinks when it cools. Student 3 recorded that soup was evaporating when eating up and precipitating when cooled down. Student 3 had a misconception that evaporation was causing the soup to heat up. This students' prior knowledge of evaporation came from a prior unit involving the water cycle and how water evaporates when it reaches a certain temperature. Although Student 3 did connect the concept of evaporation with a liquid rising, Student 3 applied it in the wrong context in this situation. Student 3 had another misconception when recording on the handout that precipitation is what was causing the soup to sink. This students' prior knowledge of precipitation came from a prior unit involving weather where it was taught that liquids fall back to Earth's surface when cooled, resulting in precipitation. Although Student 3 did connect the concept of precipitation with a liquid falling, Student 3 applied it in the wrong context in this situation.

Student 1 was observed having difficulty when moving on to the directions related to the main activity of the gizmo printed on the handout from the prior knowledge section. This difficulty was observed when noticing that the student seemed frustrated and stopped interacting with the Gizmo for a minute. This was the first language barrier observed during the facilitation of the gizmo. Student 1 was then observed putting in earbuds and using the read aloud feature on Microsoft Word to have the directions read aloud. Since this action allowed the student to specifically focus on use of the simulation and not having to interpret directions on printed text, it did not interfere with the intervention itself. After Student 1 began using the read aloud feature, the previously noticed level of frustration began to dissipate and the student was observed re-engaging with the activity. Student 1 was observed using the read aloud feature for most of the rest of the activity. When the semi-structured interview questions were verbally asked to student 1 through the gizmo, Student 1 asked several times for each question to be repeated and each question was repeated as requested. Student 1 was observed interacting with the simulation during each question by adding a drop of food coloring to the water, turning on the heater, and watching the heated liquid when it rose and fell before responding. This observed use of the simulation during each question helped to support that Student 1 was actively using the interactive simulation to verbally explain the concept during the interview. Student 1 was also ably to apply this comprehension when moving on to the second part of the gizmo simulation which involved real-world locations that received more sunlight versus less sunlight and how this impacted the water at those locations. Student 1 was able to apply this knowledge when stating during the interview that colder, denser water sunk because it had a lower temperature.

Student 2 was also observed having difficulty when moving on to the directions related to the main activity of the gizmo printed on the handout from the prior knowledge section. This difficulty was observed when noticing that the student seemed frustrated and stopped interacting with the Gizmo for a minute. This was the same language barrier observed with student 1 during the facilitation of the gizmo. Student 2 asked for the questions to be verbally read aloud, which I did. Since this action allowed the student to specifically focus on use of the simulation and not having to interpret directions on printed text, it did not interfere with the intervention itself. After Student 2 began having the questions read aloud, the previously noticed level of frustration began to dissipate and the student was observed re-engaging with the activity. Student 2 asked for most of the remaining questions printed on the handout to be read aloud for most of the rest of the activity. When the semi-structured interview questions were verbally asked to student 2 throughout the gizmo, Student 2 asked several times for each question to be repeated and each question was repeated as requested. Student 2 was observed interacting with the simulation during each question by adding a drop of food coloring to the water, turning on the heater, and watching the heated liquid when it rose and fell before responding. This observed use of the simulation during each question helped to support that Student 2 was actively using the interactive simulation to verbally explain the concept of convection during the interview. Student 2 was also able to apply this comprehension when moving on to the second part of the gizmo simulation which involved real-world locations that received more sunlight versus less sunlight and how this impacted the water there. Student 2 was able to apply this knowledge when stating during the interview that water and air at the equator was rising because it was hotter there.

However, Student 2 did not include how this process also changed the density of the water.

Student 3 was not observed having any difficulty reading the printed directions on the handout. Student 3's WIDA Access test score related to reading was higher than both student 1 and student 2. However, student 3's WIDA Access score related to speaking was the same as both student 1 and student 2. Student 3 seemed very comfortable recording answers on the handout and was observed actively using the gizmo simulation to answer the questions. When the semi-structured interview questions were verbally asked to Student 3 throughout the gizmo, student 3 was uncertain of the questions and did not immediately respond when they were read aloud. I asked if student 3 would like for the questions to be repeated when this occurred, and Student 3 responded with yes. Student 3 was observed interacting with the simulation during each question and watching the heated liquid when it rose and fell before responding. This observed use of the simulation during each question helped to support that student 3 was actively using the interactive simulation to verbally explain the concept during the interview. Student 3 was also ably to apply this comprehension when moving on to the second part of the gizmo simulation which involved real-world locations that received more sunlight versus less sunlight and how this impacted the water. Student 3 was able to apply this knowledge when stating during the interview that some of the air is heated and rises at the equator.

A follow up interview for the convection cells gizmo was conducted 4 weeks after the original semi-structured interview and gizmo use to complete the provided handout. Each student was provided with a computer with the gizmo already up in front of them during

class and asked three follow-up questions. Students were told that they could click or move anything in the gizmo as they answered the follow up questions. All three students stated that the gizmo was showing heat transfer and were able to correctly describe the movement of the heated water as it was heated and cooled. Student 1 was very active in pointing out how the droplet of food coloring that was added better showed this movement in response to the first question. Student 1 orally demonstrated this when stating that

> "when it goes to the top, it is cold and moving slow. When it goes down, it is moving faster when it is heated. It helps me to see that. Adding the drops of food coloring to the water helps me to see when the heated water rises and colder water falls"

In response to the second question asking about how the gizmo helped them to understand heat transfer by convection, both student 1 and Student 3 specifically mentioned how the gizmo helps them to understand the concept by showing them the process in action. Student 2 pointed to the fire and mentioned how the gizmo showed how the water was moving around because of the heated provided by the fire. Student 2 and Student 3 further elaborated by moving a drop of food coloring into the container of water to point out how the drop of food coloring began to move around when the water was heated. In response to the final follow-up question regarding why some bubbles were rising while other bubbles were sinking, student 1 pointed to the fire and mentioned how it was causing the bubbles to go up and the bubbles when back down on the other side when there was no heat source. Although Student 2 did not point to the fire, Student 2 mentioned that it was the reason why the bubbles were rising on one side and sinking on the other. Student 3 did not point to or mentioned the fire, but did state that heat was

causing this process to happen. While conducting this follow-up interview, all three students either pointed to specific visuals that helped them to understand the process of heat transfer or specifically mentioned that being able to see and interact with the gizmo helped them to understand the process of heat transfer.

Results of Hurricane Motion Cells Gizmo

I conducted the second interactive simulation gizmo about the motion of hurricanes with students. The learning objective of this Gizmo was to use models to describe the formation and motion of hurricanes. To demonstrate grade-level comprehension on this gizmo, students needed to be able to use the Gizmo to describe the conditions needed for hurricanes to form. This understanding involved being able to describe that hurricanes need warm water as an energy source, that hurricanes form in low pressure areas where air is rising, and that hurricanes weaken when they lose access to both the energy source and low pressure. The gizmo allowed students to observe how and where hurricanes form. Students were able to use weather stations to collect data on different conditions, such as air pressure, anywhere on the gizmo. Students were also able to observe what happens when hurricanes get to colder areas or travel over land. Each time students reset the Gizmo, a different hurricane would be present on their screen. Additionally, students were able to move hurricanes a different distance from the weather stations to collect their data. This meant that weather station readings may be slightly different between each students' recorded data, but the general understanding should still be the same when they respond to questions about the data.

All three students were seen beginning with the prior knowledge section of the handout in a similar fashion to when they began the convection cells gizmo, with all three being seen opening the program and using the gizmo actively throughout the lesson. This involved all three participants being observed using the interactive simulation program to zoom in and rewatch different phenomena occurring that caused the hurricanes to either form or begin to weaken. Student 1 and Student 3 were able to connect prior knowledge with the current concept by recording that a barometer was most likely used to predict when hurricanes were approaching prior to the invention of satellites. The connection with the domain specific vocabulary word barometer came from a previous unit involving weather and how it was a tool used to measure the air pressure. Student 2 recorded that warmer weather was most likely used to predict when a hurricane was approaching. Student 2's response most likely came from prior knowledge involving warmer weather during certain times of the year proceeding a thunderstorm. All three students tapped into some amount of prior knowledge to connect what they already knew to the current topic involving hurricanes.

Student 1 was observed having difficulty when moving on to the directions related to the main activity of the gizmo printed on the handout. This was the same language barrier observe with both student 1 and student 2 during the first gizmo over convection cells as well. Student 1 was then observed putting in earbuds and using the read aloud feature on Microsoft Word to have the directions read aloud. Since this action allowed the student to specifically focus on use of the simulation and not having to interpret directions on printed text, it did not interfere with the intervention itself. Student 1 was observed using the read aloud feature for most of the rest of the activity. When the semi-structured

interview questions were verbally asked to student 1 through the gizmo, student 1 asked several times for each question to be repeated and each question was repeated as requested. Student 1 was observed interacting with the simulation during each question and watching how the cloud cover, wind speed, air pressure, and wind direction changed as a hurricane approached a weather station. This observed use of the simulation during each question helped to support that Student 1 was actively using the interactive simulation to verbally explain the concept during the interview. Student 1 was also able to apply this comprehension when moving on to the second part of the gizmo simulation which involved what happened when the hurricane went from the ocean to the land. Student 1 was able to apply this knowledge when stating that the hurricane got smaller after it made landfall. Although Student 1 was able to make a direct observation with this gizmo, Student 1 was not able to connect the domain specific vocabulary involved with what was causing the hurricane to get smaller.

Student 2 was observed having difficulty when moving on to the directions related to the main activity of the gizmo printed on the handout. This was the same language barrier observe with both Student 1 and Student 2 during the first gizmo over convection cells as well. Student 2 was then observed putting in earbuds and using the read aloud feature on Microsoft Word to have the directions read aloud. Since this action allowed the student to specifically focus on use of the simulation and not having to interpret directions on printed text, it did not interfere with the intervention itself. Student 2 was observed using the read aloud feature for most of the rest of the activity. When the semi-structured interview questions were verbally asked to student 2 throughout the gizmo, Student 2 asked several times for each question to be repeated and each question was repeated as

requested. Student 2 was observed interacting with the simulation during each question by moving the hurricane to different places around the map and watching how the cloud cover, wind speed, air pressure, and wind direction changed as a hurricane approached a weather station. This observed use of the simulation during each question helped to support that Student 2 was actively using the interactive simulation to verbally explain the concept during the interview. Student 2 was also able to apply this comprehension when moving on to the second part of the gizmo simulation which involved what happened when the hurricane went from the ocean to the land. Student 1 was able to apply this comprehension that hurricanes need a low-pressure area to form when stating that a hurricane did not form in an area because there was not low pressure. Additionally, Student 2 stated that a hurricane got smaller when it went over the land. Student 2 was observed pointing this out in the gizmo simulation when answering each question.

Student 3 was not observed having any difficulty reading the printed directions on the handout. Student 3 seemed very comfortable recording answers on the handout and was observed actively using the gizmo simulation to answer the questions. This active discovery was noted as I observed Student 3 moving the hurricane to different spots and using the data from weather stations and hurricane size to answer the questions. When the semi-structured interview questions were verbally asked to student 3 throughout the gizmo, student 3 acted uncertain of the answer. This same observation was made during the convection cells gizmo as well for Student 3. This uncertainty with speaking answers seems to be linked with Student 3's lower speaking comprehension, based on the WIDA scores. Although Student 3's overall WIDA score is a 4.8, his speaking score is a 3.8. Having a 3.8 speaking score puts him in the developing range where he knows and uses

social English orally and some specific academic language orally with visual support. I asked if Student 3 would like for the questions to be repeated when this occurred, and Student 3 responded with yes. Student 3 was observed interacting with the simulation by moving the hurricane near a weather station during each question and watching how the cloud cover, wind speed, air pressure, and wind direction changed as a hurricane approached a weather station. Since Student 3 consistently interacted with the Gizmo to answer each question by moving the hurricane to different weather stations, observing the changes in air pressure, and noting the changes in hurricane size when it was over land versus over water, this helped to support that Student 3 was actively using the interactive simulation to verbally explain the concept during the interview. Student 3 was also able to apply this comprehension when moving on to the second part of the gizmo simulation which involved what happened when the hurricane went from the ocean to the land. Student 3 was able to apply this knowledge when stating that a hurricane got smaller when it lost its energy source when stating that "it loses its water, its energy". This answer was further expanded upon during the semi-structured interview when student 3 stated that the energy source for the hurricane was water.

A follow up interview for the hurricane motion gizmo was conducted four weeks after the original semi-structured interview and focused on long term retention of the content. Each student was provided with a computer with the gizmo already up in front of them during class and asked three follow-up questions. Students were told that they could click or move anything in the gizmo as they answered the follow up questions. All three students stated that being able to see and interact with the gizmo helped them to understand the movement of hurricanes and what conditions were required for them to

weaken. All three students were observed actively moving the hurricane to different spots on the gizmo to illustrate what they were talking about. Additionally, all three students also mentioned and pointed to the weather stations and how they could be used to determine if a hurricane was nearby. Student 1 mentioned how the weather stations indicated the wind speed and air pressure of a hurricane when it was nearby. Student 1 further elaborated how it was the barometer being used at the weather stations to determine the air pressure. Student 2 mentioned how the weather stations, calling them radar stations, had numbers indicating the speed and strength of a hurricane. Student 3 mentioned the circulation of a hurricane being counterclockwise and moved a hand around the screen indicating what this meant. Student 2 also mentioned how the weather station turned black to indicate cloud cover when a hurricane was close by moving a hurricane very close to the station on the computer screen. All three students waited until a hurricane was beginning to move over land within the simulation before describing how the size of the hurricane was getting smaller, indicating that the hurricane was weakening under these conditions. Student 2 further elaborated that the hurricane's wind speed, as indicated by the weather station, got slower when it weakened.

Using the constant comparative method, codes were established based on relevant themes found with the data. Participants' written answers collected with the gizmo handouts and spoken answers collected during the semi-structured interviews were further analyzed to eventually construct conclusions based on the findings. This process involved comparing pieces of written and spoken data applicable to each theme and integrating them into these themes based on their properties. Participant's contributed differing amounts of information to the two themes. Some participant's answers heavily

emphasized on one or two themes; some participants made nearly equal contributions across all two themes. Thus, all participants' answers are represented in this study. Two themes emerged from this data:

- Correct description of concept in own words
- Use of content specific vocabulary to describe concepts

While the themes are reported as being distinct, there is considerable overlap among them. Further, participants' responses to interview and handout questions often addressed more than one theme. In those cases, the interview data are described where they appear to fit most logically. Data from theme 1 corresponds to research question number 1, while data from theme 2 corresponds to research question number 2.

Theme 1: Correct description of concept in own words

This theme was related to students first describing concepts in their own words, before beginning the process to apply content specific vocabulary. The students may not have full comprehension of the vocabulary yet but were able to begin the process of acquiring the terminology by first describing what the terminology looked like in their own words. These observations were important, as they indicated a fluency first approach where the participants were able to use the interactive simulation to acquire an understanding of the content through visual representations first, then use the guiding questions on their handouts to connect the terms to what they observed.

All three participants were observed actively using the convection cells gizmo to answer both the handout questions and the semi-structured interview questions. When

presented with a question regarding how the drop of food coloring in the heated beaker moved, Students 1 and 3 used the Gizmo to correctly communicate that it went up when warmed, and down when cooled. Student 2 communicated during the interview that it rose when warmed but did not mention that it sunk when cooled. However, Student 2 did correctly record that the drop sunk when cooled on the written lab sheet. All three students' responses indicated their comprehension that warmed fluids rise and cooled fluids sink during the process of convection. All three students actively used the gizmo to observe this scientific concept using the gizmo before answering the questions during the semi-structured interview and on their written lab sheets. During the second part of the convection cells Gizmo, all three students were presented with a question regarding how convection impacts real world phenomenon. When asked how convection affects either the coast, the ocean, or the atmosphere, Students 2 and 3 correctly stated that air heats up and rises at the equator. Student 2 further elaborated that water moved downward in the North Sea when it was cold during the interview and that air near the equator rose because it was less dense on the gizmo handout. Student 1 correctly stated that water is less dense at the equator and going upward, while colder denser water sinks. Student 1 further noted in writing on the gizmo handout that the density was higher at the colder spot. Students 2 and 3 answers indicated that they understood that the equator was a warm place on Earth and that air was rising due to the warmth. Student 1 and 2 answers on the convection cells handout indicated an understanding that the warm and cooled fluids had a different density when stating that the density was higher at the colder spot. All three participants were observed going back to the gizmo to observe this phenomenon

before answering the question during the interview and when presented with similar questions on their written handout about the concept.

All three participants were observed actively using the hurricane motion gizmo to answer both the handout questions and the semi-structured interview questions. When presented with a question regarding how air pressure changes when a hurricane is near, all three students were observed using the gizmo to correctly state that air pressure decreased. When presented with another question regarding what happens to hurricanes when they reach land, students 2 and 3 correctly pointed out and stated that the hurricane was getting smaller. Student 1 stated that the hurricane was going down. However, when asked to elaborate on that statement, student 1 further responded that the hurricane's size decreased. Student 2 further pointed out that the hurricane was going to a colder area. Student 3 pointed out and stated that the hurricane was losing its water. All three participants were observed going back to the gizmo to observe this phenomenon before answering the question during the interview and when presented with similar questions on their written handout about the concept. Since students were observed using the interactive gizmo to answer each semi-structured interview question and gizmo handout question, the gizmo provided ample opportunities for each participant to develop understanding of content-specific vocabulary by observing a model of the phenomenon and first describing it in their own words. This methodology of students using experiences to first describe concepts in their own words aligns with Krashen's theory and constructivism.

All three participants were observed constantly going back to the interactive simulation and using it while completing the written handout, when answering questions

during the semi-structured interview, and when answering questions during the follow-up interview. Instead of having to focus on lengthy reading passages to learn the information presented within the objective or this activity, the technology utilized within this intervention enhanced learning for these individuals by instead allowing them to focus on visuals which they were able to interpret without language barriers being a hinderance. Although students may not have known the correct terminology behind the events occurring throughout the gizmo, they were able to observe the phenomenon occurring to describe the processes in their own words. Scientific vocabulary was then connected through prior knowledge and discussion questions, aligning with Krashen's monitor hypothesis that a fluency first approach is effective in supporting ELL's vocabulary acquisition. All three participants were observed using the interactive simulation program to zoom in and rewatch different phenomena occurring during both the convection currents gizmo and hurricane motion gizmo. None of the participants were stressed when learning the information presented within the activity, since each was able to use the interactive visual nature of the simulations to learn the content without having to worry about complex text and diagrams which they would have to interpret. These observations align with Krashen's input hypothesis involving the use of comprehensible input, or natural communicative input that is understood through any potential language barriers. Additionally, these observations align with Krashen's affective filter hypothesis related to anxiety and how it may either prevent comprehensible input from being used through mental blocks or promote acquisition. Since students were able to easily interpret the visual simulations, they had low anxiety during the process. Participants were also able explain the content within their own words without domain specific vocabulary being

utilized at first. Since the learning objective of this gizmo was to use models to describe the process of convection and how it impacts real world phenomenon, written and oral responses needed to correspond to this objective for students to have met the state standard and master the concept. The following figure outlines findings from theme 1, which corresponds to research question number 1, and supportive data which was used to draw conclusions.

Research Question	Supportive Data 1	Supportive Data 2	Supportive Data 3
How does the use of digital simulations provide opportunities for English Language Learners to develop understanding of content-specific vocabulary in middle school science? **(Theme 1)**	Student 1 and Student 2 correctly applied the content specific vocabulary term dense when discussing how liquids and gases rise or sink due their density. Both also communicated that density was higher at a colder location.	Student 2 and student 3 correctly applied the content specific vocabulary word air pressure when stating that the air pressure decreased whenever a hurricane was near and further elaborated that all hurricanes seemed to need low pressure.	Student 2 and student 3 correctly applied the content specific vocabulary word equator when stating that air heats up and rises at the equator. Student 1 correctly stated that water is less dense at the equator and going upward.
I conclude that interactive Gizmos simulations increase verbal and written comprehension of science content with middle level English language learner students.			

Figure 4.1: Conclusions from Theme 1

Theme 2: Use of content specific vocabulary to describe concepts

This theme was related to students fine tuning their understanding of content specific vocabulary to more precisely use it to describe concepts in a more complex manner. Now that each participant had an opportunity to first acquire the vocabulary through a fluency first approach, they then had to correctly apply the specific vocabulary. Furthermore, theme two more adequately represents grade level mastery of the material since the learning objective of both Gizmo simulations was for students to use models to describe concepts. If students were able to use the Gizmos to describe the concepts involved using content specific vocabulary correctly, they were considered to be on grade level for meeting expectations on each of the state standards addressed within the Gizmo simulations.

All three student's answers which involved application of content specific vocabulary typically showed up near the last interview questions and the middle to last questions on the gizmo handouts, after they had many opportunities to describe the content in their own words based on the visual observations. When presented with a question on the convection cells gizmo during the semi-structured interview about how convection affects either the oceans, the coast, or the atmosphere, Student 1 correctly applied the content specific vocabulary term "dense". The term density involves how closes or spread apart the water or air molecules are within a substance. Student 1 correctly used the term to state that air at the equator was less dense because it was going upward and denser when it was colder and sinking. Student 1 further expanded upon this when correctly applying the concept specific vocabulary word temperature to state that the cold water had less temperature. Student 2 and student 3 correctly applied the content specific vocabulary word equator when stating that air heats up and rises at the equator.

When presented with a question on the hurricane motion gizmo during the semi-structured interview about what they noticed about a weather station when a hurricane was getting close, student 3 correctly applied the content specific vocabulary word air pressure when stating that the air pressure decreased whenever a hurricane was near and further elaborated that all hurricanes seemed to need low pressure. Student 1 and Student 2 mentioned air pressure during the semi-structured interview but did not correctly answer why hurricanes are produced in low pressure areas. However, when presented with a similar question on the written handout about whether they thought a hurricane was nearby without being able to see it, student 2 did correctly apply this vocabulary term when writing that there was not a hurricane nearby because there were no areas of low pressure. Since students were observed using the interactive gizmo to answer each semi-structured interview question and gizmo handout question, the gizmo provided ample opportunities for each participant to develop understanding of content-specific vocabulary in middle school science. While each student first was able to analyze and describe concepts in their own words, this transition to each student applying content specific vocabulary orally by the end of the semi-structured interview and written on their gizmo handouts. Each gizmo lab sheet completed by each student is provided in the Appendices. Since the learning objective of this gizmo was to use models to describe the formation and motion of hurricanes, written and oral responses needed to correspond to this objective for students to have met the state standard and master the concept. The following figure outlines findings from theme 2, which corresponds to research question number 2, and supportive data which was used to draw conclusions.

Research Question	Supportive Data 1	Supportive Data 2	Supportive Data 3	Supportive Data 4
What impact, if any, does a digital simulation game have on ELL learner ability to understand science at a proficient level (on a level with their peers of similar age/grade)? **(Theme 2)**	All three students' responses indicated their comprehension that warmed fluids rise and cooled fluids sink during the process of convection.	All three students were observed using the gizmo to correctly state that air pressure decreased when a hurricane was nearby.	Student 1 and 2 answers indicated an understanding that the warm and cooled fluids had a different density.	Student 2 and 3 answers indicated an understanding that hurricanes weaken when they reach land due to losing access to their energy source.
I conclude that digital simulation games have a positive affect on ELL learner ability to understand science at a proficient level due to the visual connections that they provide that maximize comprehensible input.				

Figure 4.2: Conclusions from Theme 2

Summary

In this chapter, I presented the findings of this study. These findings are based primarily on analysis of observations, semi-structured interviews, and student artifacts through gizmo handouts. Findings were discussed in parts based on how they correspond with the major themes that emerged from the data. Data from the first part focused on students oral and written responses during the convection cells gizmo case and the impact which the digital simulation provided opportunities for the English Language Learners to develop understanding of content-specific vocabulary in middle school science. Data from the second part focused on students oral and written responses during the hurricane

motion gizmo case and the impact which the digital simulation provided opportunities for the English Language Learners to develop understanding of content specific vocabulary in middle school science. In the area of data collection, questions were described which were presented to students while each student was using the gizmo and their answers noted both from the interview and the handout. In the area of data analysis, students use of the gizmos to answer each question was analyzed along with their answers themselves. These answers were then grouped based on relevant themes found with the data.

Chapter 5

Implications

This chapter reiterates the problem of practice which I identified in relation to ELL achievement in a middle grades science class, the research question investigated during this study, the purpose of the study, an overview of the methodology used, results of my findings, and the practice recommendations and implications of the results. This last section will further elaborate on how the results will be further utilized and communicated with other relevant stakeholders who may possibly benefit from making a similar intervention within their own class. Furthermore, this last section will discuss future research plants which can delve deeper into results to further benefit ELL students based on the relationship between the types of instruction which are provided to facilitate the teaching of content for them.

Problem of Practice

The identified problem of practice was that ELL students are underperforming their peers in the science classroom due to curriculum input that is not comprehensible based on student's language acquisition levels. This was evident based on personal experience with students who had limited English proficiency, meaning they had WIDA ACCESS Test scores between a one and a five, struggling with both verbal and written comprehension of the subject matter on a variety of formative and summative assessments. Additionally, a recent report card from the South Carolina Palmetto

Assessment of State Standards (SCPASS) showed the respective proficiency rates for fourth and eighth grades in the school district where this study was conducted stood at thirty-six percent and forty-two percent in science (South Carolina Department of Education, 2021). State scores for this same assessment were forty-four percent and forty-two percent. Fourth and sixth grade scores for ELL students, indicated as students who were limited English proficient on the state report card, stood at thirty-six percent and thirty-five percent. These data show that ELL students within the state with limited English proficiency scored eight percentage points lower in fourth grade and seven percentage points lower in sixth grade. These data suggests that although the standards themselves have changed to promote more real-world thinking and integration of science content, that actual strategies being used in classrooms may not be aligned to best meet the needs of ELL students.

Research Questions

The following research questions were included to study the impact of Gizmos on English language learner comprehension:

1. How does the use of digital simulations provide opportunities for English Language Learners to develop understanding of content-specific vocabulary in middle school science?
2. What impact, if any, does a digital simulation game have on ELL learner ability to understand science at a proficient level (on a level with their peers of similar age/grade)

These specific research questions were selected due to the focus on how the intervention would impact ELL students' understanding of science concepts. Understanding was defined as verbal and written comprehension of the concept in their own words followed by the association of content-specific terminology with the concept. Verbal and written comprehension were chosen together in order to provide a comprehensive view on the relationship between using interactive simulations with Gizmos and ELL students' ability to acquire the content. This intervention was chosen due to the programs ability to facilitate the teaching of content in a way that is interactive, reduces verbal and textual language barriers, and helps students to connect their prior knowledge and real-world experiences to the content.

Purpose of Study

The purpose of this study was to determine how a particular technology program, Gizmos, would impact ELL students in demonstrating their verbal and written comprehension of science content. Gizmos were incorporated as an intervention to facilitate the teaching of two different topics, convection cells and hurricane motion.

Overview of Methodology

This study incorporated action research which allows educators to look at their specific population of students and make necessary adjustments based on data to best meet their needs. This description of action research is supported by Efron and Ravid (2013) when stating that "action research is usually defined as an inquiry conducted by educators in their own settings in order to advance their practice and improve their students' learning (pg. 2). Since ELL students are often impeded by language barriers in

their acquisition of content, qualitative action research was used to focus on collecting multiple types of descriptive data for a more holistic approach to understanding the impact of the intervention. A holistic approach “involves reporting multiple perspectives, identifying the many factors involved in a situation, and generally sketching the larger picture that emerges” (Creswell, 2014, p.235). The three types of data collected during this study were semi-structured observations, semi-structured interviews, and student handouts collected daily during the use of each interactive gizmo simulation.

Findings

My analysis demonstrated a strong correlation between the use of Gizmos with English language learner’s written and oral comprehension of science content. My findings from theme 1, research question number 1, is that interactive Gizmos simulations increase verbal and written comprehension of science content with middle level English language learner students. My findings from theme 2, research question number 2, is that digital simulation games have a positive effect on ELL learner ability to understand science at a proficient level due to the visual connections that they provide that maximize comprehensible input. Conclusions related to student improvements is being based on observations from a variety of formative and summative assessments given to them in class at first, then I noticed improvement afterward. In addition, these students reported guessing on most of the questions which contained specific academic vocabulary. Each of these three participants struggled daily with being able to demonstrate written and oral comprehension of the content before the integration of interactive Gizmos simulations. The only scaffolds put into place before incorporation of Gizmos were from recommendations from the school-based ELL support teacher and

were based on their WIDA Access Test scores and included: Provision of a copy of the notes for each topic or completion of notes through a graphic organizer, use of a bilingual dictionary, extended time for assignments/assessments, and rewording of directions.

My results corroborate Finlinson (2016) and Goldenberg (2008) studies by supporting the use of meaningful activities which utilize comprehensible input through task-based activities instead of direct instruction. My results also support the findings of Short (2016) when discussing how the use visuals and modeling are effective to present key information to ELL students. My results related to the use of Gizmos also supports the findings of Cutter (2015), Diallo (2014), Toscano and Rizopoulos (2013), and Abdul (2018), who discussed how technology plays a key role by assisting educators in the creation of leaning environments were comprehensible input contributes to the lowering of ELL students' affective filter. This affective filter dealt with providing comprehensible input that lowered students' anxiety and stress as they attempted to learn the content through the interactive Gizmos simulations. The lower the affective filter, the more engaged students are in their learning. Furthermore, my results also correspond to the importance of the teacher being present when technology supported instruction is being utilized discussed by Crum (2017) and Fox (2014). This is because my role in content understanding during the Gizmos was that of a facilitator with the students being involved in learning the content through their own active discovery. I did not have to answer any questions regarding the content while the participants worked through each gizmo. The only questions asked were ones provided in the semi-structured interview and follow up interview. Ramirez (2012) discussed how new technologies have created new possibilities to incorporate visual aids within the classroom but are yet to be fully

exploited in a systemic matter. Since my study did incorporate interactive visual aids within the classroom exploited in a systematic matter, the results corroborate Ramirez' statement. This is because all three participants were observed actively using the Gizmos simulations throughout the study to acquire content understanding and vocabulary. My findings refuted those of Irbi et al. (2018) who reported that ELL students were less likely to become engaged in computer simulations unless student to student collaboration was included within instruction. This is significant since my study involved incorporating interactive simulations on an individual basis and not a collaborative one. Although collaboration was not involved, all three participants were observed being actively engaged in using the simulations and were able to demonstrate grade level written and oral comprehension based on the learning objectives outlined within each Gizmo.

The most closely related research to my own within my literature review were studies from Head (2014), Ranalli (2008), and Smith (2013). Head and Ranalli's studies focused on the impact of computer simulations on ELL students' comprehension, while Smith's study focused on the impact of interactive computer simulations on student achievement. Head's study indicated findings which supported computer simulations with assisting ELL students with grasping concepts, while Ranalli's study indicated statistically significant improvements in vocabulary knowledge. Smith's study also incorporated Gizmos as the intervention used with students and had results which "validated that web-based simulations used in conjunction with other instructional methodologies made enough of a difference in closing achievement gaps among certain at-risk populations to justify continued use of online simulations and warrant further research on Gizmo's efficacy in reaching struggling learners" (Smith, 2013, p. 1). My

own study supported them by showing that interactive Gizmos simulations are able to provide more comprehensible input for ELL students that maximizes visuals while reducing text heavy passages to facilitate the teaching of content. This in turn lowers the students affective filter and keeps them more engaged. Smith’s (2013) indication that further research on Gizmo’s efficacy in reaching struggling learners, and the fact that no other similar studies with Gizmos use with ELL students could be located, help my own study to expand upon the existing literature related to the constructs and variables. My study will help to improve the existing literature and knowledge base in the field by showing how interactive simulations allow ELL students to learn the content through visuals, reducing the impact of language barriers in the process of learning. Furthermore, ELL’s demonstration of comprehension using interactive Gizmos simulations is at the proficient level. This level of proficiency is based on the outlined learning objectives for each Gizmo, which in turn correspond to the grade-level learning objectives for what students are expected to know and do for each concept.

Action Plan

Next steps that I see for this type of research include conducting similar studies with larger sample sizes to determine if the impact of interactive simulations using the gizmos program has similar impacts across various populations. While I was limited to a small sample size within this study since I only personally instructed three ELL students with WIDA levels classified within the LEP range, conducting similar studies in subsequent years and including other grade levels and schools could be used to compare results to look for any similarities. Additionally, I only incorporated two gizmos within this study pertaining to heat transfer and weather. I plan to expand upon this by utilizing a

greater variety of gizmos offered by the program to determine if other concepts will have similar results. Gizmos currently has interactive simulations for topics in every middle school grade level which are all aligned to the South Carolina state standards (South Carolina Department of Education, 2021). Conducting a yearlong study with a larger variety of topics across multiple grade levels will help to determine if similar results will span across numerous scientific concepts.

Practice Recommendations and Implications

Since my findings indicate a benefit to using interactive simulations, Gizmos specifically, to help support ELL students' comprehension of concepts in middle school science, several practices can be improved upon. Since Gizmos are aligned with state science standards, I plan to incorporate them within my own instruction on a weekly basis to better support English language learners. I have already identified specific Gizmos for facilitating the teaching of content for all students within both grade levels which I specifically work with. Additionally, these Gizmos have been added to my digital learning platform which students will access for the remainder of the school year, and future school years for new groups of students. Since the students involved within this study had been using the Gizmos program prior to the intervention taking place with different topics, each was proficient in the technical aspects of how to navigate through the program itself. I would recommend using Gizmos on a consistent basis to promote a technical understanding of how the program works, as well as to facilitate and guide students through several to ensure they know how to navigate the program. However, evidence from this study suggests that this technology driven program enhances learning for English Language Learners in both written and spoken comprehension.

While this study is intended to generate local, context dependent knowledge, it is not intended to be generalizable or demonstrate external validity. However, sharing practitioner-research can be evocative and transferable. With evocation and transferability in mind, additional stakeholders may include other middle school science teachers who work with ELL students. These science teachers might gain a better understanding of how they can analyze their own instructional practices that are being used to facilitate teaching the content to ELL students and interventions that they may find useful in bridging achievement gaps in student comprehension. As a member of my school district's curriculum support team, and my role as a lead teacher in helping to facilitate professional development opportunities across the school district, I plan to share the process and results of this action research study and work with other teachers in using interactive simulations within their own classrooms. This will be accomplished through the facilitation of professional development opportunities across the school district. I will ensure that my study and results are put into action by promoting organizational change in how science content is taught at the middle school level. Since science standards are shifting to a focus on phenomena first based instruction, Gizmos would be an effective tool to promote and incorporate into my school district's curriculum support documents and professional development initiatives.

This process helped me to gain a better understanding of a specific problem of practice within my instructional area. I was able gain a better understanding of how the Gizmos program can support ELL students which I teach by providing more visual, comprehensible input which reduces the impact of language barriers in the learning process. Connections through vertical alignment of content, real word integrations, and

visual representations that can be manipulated by the student when using Gizmos. The language barriers that were reduced by using Gizmos include the students having access to more interactive visuals instead of reading complex text when learning about new content. Based on the results from my study, I would suggest Gizmos be used as a means of replacing text heavy activities to better support content acquisition for ELL students. Since two out of the three participants within this study were initially hindered by printed text for instructions and questions provided on the Gizmos handouts, I would suggest teachers either direct students to use the read aloud feature embedded within Microsoft Word, or personally read the text aloud to ELL students. Furthermore, adequate time needs to be provided for ELL students to re-watch and synthesize the models involved within Gizmos simulations. This can be accomplished by dedicating one to two class periods per Gizmo. The prior knowledge that ELL students bring with them can be connected to current content in the English language through the incorporation of comprehensible input. This can be achieved by using the prior knowledge sections found in each Gizmos handout to gauge what each ELL student already knows about the content, asking them to share their prior knowledge, and facilitating the connection from prior knowledge to new content acquisition through formative questioning and time to explore each Gizmo simulation in an interactive and meaningful way. Additions to methods that could have strengthened the study include a larger sample size and use of additional Gizmos. The sample size was limited to three since I only taught three ELL students within WIDA ACCESS levels between one of four. Students who have an English Language (EL) status between one and four, based on scores from the WIDA ACCESS test, are considered to have limited English proficiency (LEP).

This research study attempted to increase understanding of the impact which interactive simulations had on English language learner's understanding of science concepts. The fact that ELL students are underperforming their peers in the science classroom due to curriculum input that is not comprehensible based on student's language acquisition levels and that many current available resources within the curriculum fail to account for how ELL students can interpret the visuals without language being a barrier in the process supported the need for my action research study in this area. The qualitative case study methodology utilized in this study offered a detailed examination of the extent which digital, interactive simulations provide opportunities for English Language Learners to develop understanding of content-specific vocabulary in middle school science

Although this study represents a start for developing a larger body of research on the relationship between the types of instruction which are provided to facilitate the teaching of content for ELL students, further research is necessary. First, future yearly action research studies with Gizmos and how they impact different groups of ELL students from different backgrounds who I teach will be used to determine of only these three students benefitted, or if these results could expand to additional populations. These additional populations include students who are struggling readers due to reading below grade level and students with disabilities. Gizmos simulations were able to support ELL students by the reduction of language barriers through more visual, comprehensible input. This same reduction may also be seen with struggling readers who get caught up in excessive texts which are hard to understand when learning scientific concepts. Second, I plan to conduct a study involving other schools and classrooms to determine if different

settings corroborate the findings from my own study. Finally, I plan to conduct a study which focuses on teachers' comfort levels in using interactive simulations such as Gizmos within their classrooms and what initiatives may impact their greater utilization. Since challenges for teachers in the implementation of technology supported instruction include teachers and students not being digital natives, this area of research will help to better support more widespread implementation of these types of instructional strategies. Since there is little evidence, based on my literature review, of studies specifically involving the impact of Gizmos on ELL students' comprehension of science concepts at the middle school level, there is a research gap in this area. The following figure outlines both the implications and action plan related to my study:

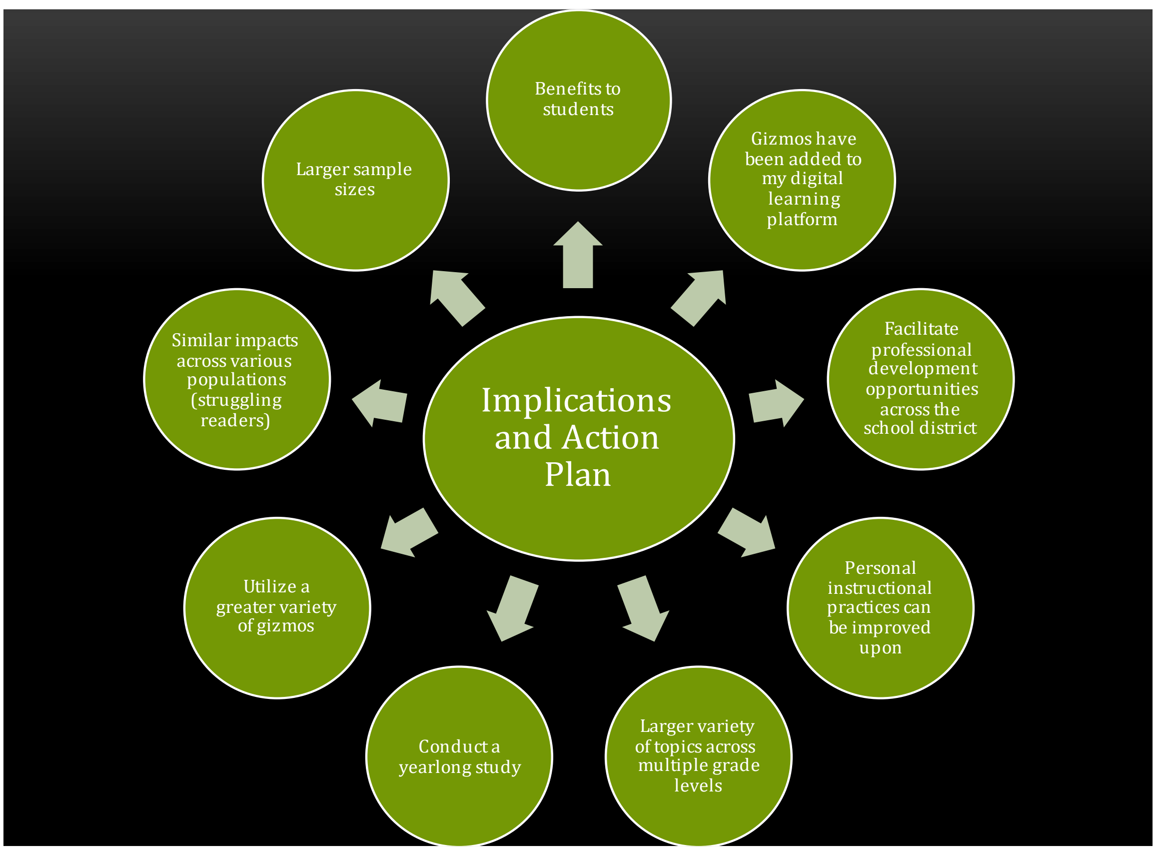

Figure 5.1: Implications and Action Plan

Vocabulary acquisition and integration is a complex process for English language learning students, with many teachers having misconceptions of student mastery of the language. Teachers often correlate mastery of conversational English with mastery of the language, which can lead to instruction that does not account for students' lack of understanding with specific academic vocabulary. Incorporating comprehensible input through interactive simulations, such as Gizmos, into the curriculum for ELL students may help in improving their academic understanding and success. The data collected from the observations, semi-structured interviews, and student artifacts in this case study support the use of interactive simulations in providing more comprehensible input for ELL students when teaching science concepts and vocabulary. The results of this study suggest that interactive simulations, specifically Gizmos, can have a positive impact on ELL students' ability to acquire the content. This is due to the programs ability to present science in an interactive, visual way which reduces verbal and textual language barriers.

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APPENDIX A: Convection Cells Gizmo Data

Table A.1: Semi-Structured Interview from Convection Cells Gizmo

Main Questions	Clarifying Questions
What do you notice about how the drops of food coloring in the heated beaker move? • Student 1 Answer: "*It is going up and down"* • Student 2 Answer: *"It rose and sunk at the same time"* • Student 3 Answer: *"It rose when it was closer to the heat. The drop sunk when it got further away from the heat"*	**Why do you think that the drops of food coloring move that way?** • Student 1 Answer: *"Because it's hot when it goes up". Because it's cold when it goes down"* • Student 2 Answer: *"The warm made it rise. The warm caused it to sink"* • Student 3 Answer: *"When it gets hot, it wants to evaporate"*

Based on what you did in activity A, can you tell me what convection is? • Student 1 Answer: *"Where is the hottest location"* • Student 2 Answer: *"The drop is going up and down"* • Student 3 Answer: *"Convection is when water evaporates and makes a cloud"*	**Why do you think that convection happens?** • Student 1 Answer: *"When it gets hot, it goes upward"* • Student 2 Answer: *"It is up when it is cold. It is hot when it went down"* • Student 3 Answer: *"The sun. The sun is heating up the water"*
Based on what you did in activity C, can you tell me how convection affects either the oceans, the coast, or the atmosphere? • Student 1 Answer: *"The equator less dense because it is going upwards"* • Student 2 Answer: *"Air heats up and rises at the equator"* • Student 3 Answer: *"Some of the air is heated up and rises at the equator"*	**Why do you think that convection affects it (the ocean, the coast, or the atmosphere) in that way?** • Student 1 Answer: *"Because the colder, denser water sinks"* *"It has less temperature"* • Student 2 Answer: *"Because it heated up"* • Student 3 Answer: *"Because it heated up"*

Virtual Lab (Gizmo): Convection Cells

Vocabulary: convection, convection cell, density, global conveyor belt, mantle, mid-ocean ridge, subduction zone, vector, viscosity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
You place a pot of soup on the stove. As the soup warms you notice some areas where soup is rising up and other areas where soup is sinking down.

1. Why do you think some of the soup is rising up?

   It is boiling

2. Why do you think some of the soup is sinking down?

   So it is getting colder and its going sink

Gizmo Warm-up
When fluids (gases or liquids) are heated, they tend to move. This motion is called **convection**. In the *Convection Cells* Gizmo, you will observe and experiment with convection both in a laboratory setting and in several real-world examples.

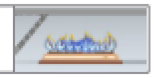
To begin, note the laboratory setup on the MODEL tab. A beaker of liquid is placed above a gas burner. Click **Play** (▶). The burner is now heating the fluid.

1. Drag the eyedropper into the beaker just above the burner and let go to release a drop of orange liquid into the beaker. What do you notice about the path of the drop?

   It is like when you put the button motion and it showing that is it going down when it is getting hot when it is like

Figure A.1: Student 1 handout from Convection Cells Gizmo – Part 1

____
___

Activity A: Convection	Get the Gizmo ready: • Click **Reset** (↺), and set **Burner A** to **High**.	

Question: What causes convection cells to form?

1. Hypothesize: Click **Play**, add a drop, and watch the motion of the liquid. Why do you think convection tends to occur in heated fluids?

   It was rising because it is hot and when it was sinking it was getting colder __________
   ____
   ___
   ____
   ____

2. Observe: Click **Clear drop**. Under **Show**, select **Temperature**. The temperature scale runs from red (hot) to dark blue (colder).

   A. Where is the hottest liquid located? Bottom left ____________________________________

   B. Where is the coldest liquid located? Upper Right____________________________________

   C. Add a drop. Does the hottest liquid tend to rise or sink? The hottest is the dot is sinking.______________________

   D. Does the coldest liquid tend to rise or sink? sink___________________

3. Observe: Click **Clear drop**, and then add a new drop to the liquid. Turn on **Show micro view of drop**. This view shows 21 molecules in the drop. Pay attention to how fast the molecules move and how much space they occupy as the drop moves around the beaker. (Note: If the drop gets stuck, add a new drop to the beaker.)

   A. In which part of the beaker do the liquid molecules move fastest? It move fast at the hot area_______________

   B. In which part are the liquid molecules most spread out? They spread out at the hot area__________________

Figure A.2: Student 1 handout from Convection Cells Gizmo – Part 2

4. Explore: Click **Clear drop** and drag the **probe** ( ) into the beaker. **Density** is defined as the mass per unit volume. It is a measure of how tightly the particles of a substance are packed. Move the probe to different parts of the beaker, observing the temperature and density.

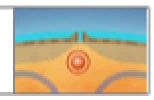
   A. What relationship do you observe between the temperature and density? The density is so higher at the colder spot _________

   ____

5. Summarize: In your own words, describe what causes convection to happen and what causes convection cells to form. So the convection is like what ever is in the middle is the hottest and what ever is at the side is the coldest.____________________________

   ____

   ____

Activity C: **Real-world convection**	Get the Gizmo ready: • Select the EXAMPLES tab.	

Introduction: The convection you observe in the lab (or in a pot of soup on the stove) also occurs on much larger scales. In this activity, you will learn about four types of convection cells that form on Earth.

Question: Where does convection occur on Earth?

1. Observe: Select **Ocean**. The **global conveyor belt** is a vast, slow-moving convection cell that connects Earth's oceans. Click each of the orange dots to read about what causes water to move up and down in the global conveyor belt.

   A. What two reasons cause water to move downward in the North Sea? The sally cold water is denser than the surrounding water________________

   ____

   B. What causes water to rise near the equator? The first one has more temperature and the other one has no temperature.________________________________

   ____

Figure A.3: Student 1 handout from Convection Cells Gizmo – Part 3

2. Observe: Select **Coast** and read about and observe convection cells that occur in the air around coastlines. Select each orange dot and see what happens during the day and night.

   A. If you are standing on a beach, why might you feel an ocean breeze during the day?

      Condensation results in cloud formation and causes rain.

3. Observe: Select **Atmosphere**. The atmosphere contains three large-scale convection cells. Click **Play** to observe these cells, and then select each orange dot to learn more.

   A. What causes air to rise near the equator? Air is heated near the equator and rises.

   B. What causes air to sink near the latitude 30° N (and 30° S)?

   C. Why are climates generally wet near the equator, and generally dry around the latitudes 30° N and 30° S?

Figure A.4: Student 1 handout from Convection Cells Gizmo – Part 4

Virtual Lab (Gizmo): Convection Cells

Vocabulary: convection, convection cell, density, global conveyor belt, mantle, mid-ocean ridge, subduction zone, vector, viscosity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
You place a pot of soup on the stove. As the soup warms you notice some areas where soup is rising up and other areas where soup is sinking down.

1. Why do you think some of the soup is rising up?

   Because its so hot

2. Why do you think some of the soup is sinking down?

   Because its cool

Gizmo Warm-up
When fluids (gases or liquids) are heated, they tend to move. This motion is called **convection**. In the *Convection Cells* Gizmo, you will observe and experiment with convection both in a laboratory setting and in several real-world examples.

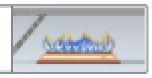
To begin, note the laboratory setup on the MODEL tab. A beaker of liquid is placed above a gas burner. Click **Play** (▶). The burner is now heating the fluid.

1. Drag the eyedropper into the beaker just above the burner and let go to release a drop of orange liquid into the beaker. What do you notice about the path of the drop?

   Because its raising then when its gets higher

Figure A.5: Student 2 handout from Convection Cells Gizmo – Part 1

____
___

Activity A: Convection	Get the Gizmo ready: • Click **Reset** ( ), and set **Burner A** to **High**.	

Question: What causes convection cells to form?

1. Hypothesize: Click **Play**, add a drop, and watch the motion of the liquid. Why do you think convection tends to occur in heated fluids?

   _______________To heat it up____

2. Observe: Click **Clear drop**. Under **Show**, select **Temperature**. The temperature scale runs from red (hot) to dark blue (colder).

   A. Where is the hottest liquid located? ____The bottom__________________________

   B. Where is the coldest liquid located? ________________At the top________________

   C. Add a drop. Does the hottest liquid tend to rise or sink? ______It goes up___________

   D. Does the coldest liquid tend to rise or sink? __________It drop to the warmse____

3. Observe: Click **Clear drop**, and then add a new drop to the liquid. Turn on **Show micro view of drop**. This view shows 21 molecules in the drop. Pay attention to how fast the molecules move and how much space they occupy as the drop moves around the beaker. (Note: If the drop gets stuck, add a new drop to the beaker.)

   A. In which part of the beaker do the liquid molecules move fastest? __________at the warmes___

   B. In which part are the liquid molecules most spread out? ______At the bottom___

4. Explore: Click **Clear drop** and drag the **probe** ( ) into the beaker. **Density** is defined as the mass per unit volume. It is a measure of how tightly the particles of a substance are packed. Move the probe to different parts of the beaker, observing the temperature and density.

Figure A.6: Student 2 handout from Convection Cells Gizmo – Part 2

A. What relationship do you observe between the temperature and density? ____It gets Warm at the bottom__

____

5. Summarize: In your own words, describe what causes convection to happen and what causes convection cells to form. _______The drop is going up and down at the same time. When it goes up it clod but when it when down it was hot_______________________________

____

____

Activity C: Real-world convection	Get the Gizmo ready: • Select the EXAMPLES tab.	

Introduction: The convection you observe in the lab (or in a pot of soup on the stove) also occurs on much larger scales. In this activity, you will learn about four types of convection cells that form on Earth.

Question: Where does convection occur on Earth?

1. Observe: Select **Ocean**. The **global conveyor belt** is a vast, slow-moving convection cell that connects Earth's oceans. Click each of the orange dots to read about what causes water to move up and down in the global conveyor belt.

   A. What two reasons cause water to move downward in the North Sea? _So it will be Cold in north sea__________

   ____

   B. What causes water to rise near the equator? ___The equator and less dense_ 22 % c____________________

   ____

2. Observe: Select **Coast** and read about and observe convection cells that occur in the air around coastlines. Select each orange dot and see what happens during the day and night.

   A. If you are standing on a beach, why might you feel an ocean breeze during the day?

Figure A.7: Student 2 handout from Convection Cells Gizmo – Part 3

___The warmth air and but the air is cool____

____

3. Observe: Select **Atmosphere**. The atmosphere contains three large-scale convection cells. Click **Play** to observe these cells, and then select each orange dot to learn more.

A. What causes air to rise near the equator? __________The equator it is going to the near to the top________________________

____

B. What causes air to sink near the latitude 30° N (and 30° S)? tend to be dry.__________________

____

C. Why are climates generally wet near the equator, and generally dry around the latitudes 30° N and 30° S? __________the latitude,   equators' are a climate to see the__________________________

____

Figure A.8: Student 2 handout from Convection Cells Gizmo – Part 4

Virtual Lab (Gizmo): Convection Cells

Vocabulary: convection, convection cell, density, global conveyor belt, mantle, mid-ocean ridge, subduction zone, vector, viscosity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
You place a pot of soup on the stove. As the soup warms you notice some areas where soup is rising up and other areas where soup is sinking down.

1. Why do you think some of the soup is rising up?

   Because of evaporation

2. Why do you think some of the soup is sinking down?

   Because of precipitation

Gizmo Warm-up
When fluids (gases or liquids) are heated, they tend to move. This motion is called **convection**. In the *Convection Cells* Gizmo, you will observe and experiment with convection both in a laboratory setting and in several real-world examples.

To begin, note the laboratory setup on the MODEL tab. A beaker of liquid is placed above a gas burner. Click **Play** (▶). The burner is now heating the fluid.

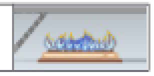
1. Drag the eyedropper into the beaker just above the burner and let go to release a drop of orange liquid into the beaker. What do you notice about the path of the drop?

   It starts going up. As is starts getting further from the heat it sinks.

Figure A.9: Student 3 handout from Convection Cells Gizmo – Part 1

____

___

Activity A: Convection	Get the Gizmo ready: • Click **Reset** ( ), and set **Burner A** to **High**.	

Question: What causes convection cells to form?

1. Hypothesize: Click **Play**, add a drop, and watch the motion of the liquid. Why do you think convection tends to occur in heated fluids?

   ___Because it melts them to a liquid.________________________________

2. Observe: Click **Clear drop**. Under **Show**, select **Temperature**. The temperature scale runs from red (hot) to dark blue (colder).

   A. Where is the hottest liquid located? ____On top of the burning fire__________

   B. Where is the coldest liquid located? ____On top or on the sides.___________

   C. Add a drop. Does the hottest liquid tend to rise or sink? _______Rise.________

   D. Does the coldest liquid tend to rise or sink? ____Sink.______________

3. Observe: Click **Clear drop**, and then add a new drop to the liquid. Turn on **Show micro view of drop**. This view shows 21 molecules in the drop. Pay attention to how fast the molecules move and how much space they occupy as the drop moves around the beaker. (Note: If the drop gets stuck, add a new drop to the beaker.)

   A. In which part of the beaker do the liquid molecules move fastest? ____When they are at the bottom.__________

   B. In which part are the liquid molecules most spread out? ______When it was at the top ______

4. Explore: Click **Clear drop** and drag the **probe** ( ) into the beaker. **Density** is defined as the mass per unit volume. It is a measure of how tightly the particles of a substance are packed. Move the probe to different parts of the beaker, observing the temperature and density.

   A. What relationship do you observe between the temperature and density? ____

Figure A.10: Student 3 handout from Convection Cells Gizmo – Part 2

________________________________ The relationship that temperature and density have is that density can be how cold something is and temperature can to. ________________________________

5. Summarize: In your own words, describe what causes convection to happen and what causes convection cells to form. ______ Convection is when water evaporates and makes a cloud. ____

____

____

Activity C: **Real-world convection**	Get the Gizmo ready: • Select the EXAMPLES tab.	

Introduction: The convection you observe in the lab (or in a pot of soup on the stove) also occurs on much larger scales. In this activity, you will learn about four types of convection cells that form on Earth.

Question: Where does convection occur on Earth?

1. Observe: Select **Ocean**. The **global conveyor belt** is a vast, slow-moving convection cell that connects Earth's oceans. Click each of the orange dots to read about what causes water to move up and down in the global conveyor belt.

   A. What two reasons cause water to move downward in the North Sea? ________

   ________________________ Because of the water that is more salty and not freeze and it has more density ________________________

   B. What causes water to rise near the equator? ________________________

   ____________________ Because of it warming up ____________________

2. Observe: Select **Coast** and read about and observe convection cells that occur in the air around coastlines. Select each orange dot and see what happens during the day and night.

   A. If you are standing on a beach, why might you feel an ocean breeze during the day?

   ________________________________ Because the air is going in a cycle ________________________

Figure A.11: Student 3 handout from Convection Cells Gizmo – Part 3

3. Observe: Select **Atmosphere**. The atmosphere contains three large-scale convection cells. Click **Play** to observe these cells, and then select each orange dot to learn more.

   A. What causes air to rise near the equator? the air is heated and it goes to the equator

   B. What causes air to sink near the latitude 30° N (and 30° S)?

      Something called Hadley cell.

   C. Why are climates generally wet near the equator, and generally dry around the latitudes 30° N and 30° S? some air heats up and some doesnt

Figure A.12: Student 3 handout from Convection Cells Gizmo – Part 4

Table A.2: Follow-Up Interview from Convection Cells Gizmo

Follow-Up Questions	**Student Responses**
What is this gizmo showing? Tell me what you see happening?	Student 1 Response • *"There is a drop, it is going down and up. I see the heat going upward"* Student 2 Response • *"It is showing heat transfer. I can see the fire. The heat is moving"* Student 3 Response • *"It is showing heat. The water is being heated and there are bubbles moving around in a circle"*

How does this gizmo help you to understand heat transfer by convection?	Student 1 Response • *“When it goes to the top, it is cold and moving slow. When it goes down, it is moving faster when it is heated. It helps me to see that. Adding the drops of food coloring to the water helps me to see when the heated water rises and colder water falls”* Student 2 Response • *“The water is moving around because of the fire. When the water is warm, the drop of food coloring moves around”* Student 3 Response • *“It shows me how heat transfers. The drops of food coloring showed me how the water moves when heated”*

The bubbles show how heat is moving. Why are some bubbles rising while other bubbles are sinking?	Student 1 Response • *"It's the gas that's doing that. This right here (student 1 points to the fire) is what is causing the bubbles to go up. The bubbles go back down when there is no heat"* Student 2 Response • *"Heat transfer. They are rising on the side the fire is on. They are sinking because it is cold on the other side"* Student 3 Response • *"When they get hot, they go up. They are cold when they go down"*

APPENDIX B: Hurricane Motion Gizmo Data

Table B.1: Semi-Structured Interview from Hurricane Motion Gizmo

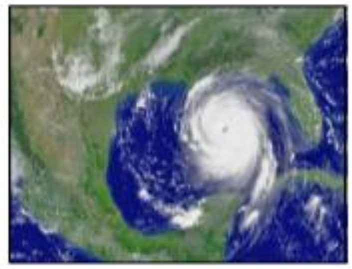
Main Questions	**Clarifying Questions**
What do you notice about a weather station when a hurricane is getting close to it? • Student 1 Answer: *"It was decreasing"* • Student 2 Answer: *"Small air pressure. Dark circle"* • Student 3 Answer: *"More darker. Like, bigger line. Air pressure decreases"*	**Why do you think that the air pressure changes that way?** • Student 1 Answer: *"Because whenever I started moving it, it kept going down by 1"* • Student 2 Answer: *"The air was going north"* • Student 3 Answer: *"Because hurricanes need low pressure"*
What happens to the hurricane after it begins moving over land? • Student 1 Answer: *"It's going down"* • Student 2 Answer: *"It is getting smaller and smaller"* • Student 3 Answer: *"It gets smaller and smaller"*	**Why do you think that the hurricane changes that way?** • Student 1 Answer: *"Because I think it was going lower. The size decreased"* • Student 2 Answer: *"It gets to a colder area"* • Student 3 Answer: *"It loses its water, its energy"*

Virtual Lab (Gizmo): Hurricane Motion

Vocabulary: air pressure, Coriolis effect, eye, hurricane, knot, meteorologist, precipitation

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
A **hurricane** is a large, rotating tropical storm with wind speeds of at least 74 miles per hour. Since 1990, **meteorologists** have regularly used satellite images to track hurricanes.

1. The satellite image at right shows Hurricane Katrina just before it hit New Orleans in 2005. Label the hurricane on the image.



2. How do you think meteorologists predicted the arrival of a hurricane before the 1990s?

   A batomer is a weather interment

Gizmo Warm-up
You can use data collected from weather stations to study the characteristics of hurricanes. The *Hurricane Motion* Gizmo has three simulated weather stations. Turn on **Show weather station data**. Make sure **Wind**, **Cloud cover**, and **Pressure** are all checked.

The tails on each station symbol point in the direction the wind is coming from. The flags on the tail indicate wind speed, measured in **knots**. (One knot is equal to 1.15 mph.) A short line extending from the tail indicates 5 knots of wind. A longer line indicates 10 knots. A triangular flag indicates 50 knots. Add all the flags together to get the wind speed.

The number in the station's upper right is the **air pressure**, which is measured in millibars (mb).

The circle symbol indicates the percentage of cloud cover, as shown in the table at right.

Degree of Cloud Cover

Clear	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Overcast
○	⦶	◔	◔	◑	◑	◕	◕	●

Use the information above to complete this table for station **A** on the Gizmo.

Wind speed (knots)	Wind from	Cloud cover	Pressure (mb)
None	West	3/8	1025.7

Figure B.1: Student 1 Handout – Hurricane Motion Gizmo – Part 1

Activity B: Predict hurricanes	Get the Gizmo ready: • Select **Experiment** and click **Pause** ( ).	

Introduction: Hurricanes form when an area of low-pressure forms over warm water. Winds blow toward the low pressure, but are deflected by Earth's rotation. The **Coriolis effect** causes winds to curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This results in a counterclockwise rotation for Northern Hemisphere hurricanes and a clockwise rotation for Southern Hemisphere hurricanes.

Question: How can you predict the location and path of a hurricane?

1. Observe: Click **Play** ( ), and wait until you see a hurricane approaching one of the weather stations. Click **Pause**. What changes indicate a hurricane is approaching?

   Cloud cover: overcast ___________________________ Air pressure: the air was decreasing ___________________________

   Wind speed: faster

2. Observe: Click **Play**, and wait for the hurricane to go over the land. What happens in the hours after landfall? Its sides were decreased. I think that the sides

   ____

3. Collect data: Click **Reset** ( ). Turn off **Show hurricane**. Click **Play**. When the simulation reads **Day 1, 3:00 PM**, click **Pause** and record the data from each weather station.

Station	Wind speed (knots)	Wind from	Cloud cover	Pressure (mb)
A	15	NE	0	1039.2
B	15	E	0	1039.2
C	25	SE	0	1037.9

4. Interpret: Using the readings above, do you think a hurricane is nearby? Explain.

   The wind is increasing because the wind is strongly moving fast and that the sation is at letter C.
____

   ____

5. Run Gizmo: Allow the Gizmo to run until the weather station data indicates a hurricane is nearby and will soon make landfall. Click **Pause**.

Figure B.2: Student 1 Handout – Hurricane Motion Gizmo – Part 2

A. What weather station data indicated a hurricane would soon make landfall?

Station A. the decresing part was the numbers and that is 1023.8____

B. Turn on **Show hurricane**. Was your prediction correct? Explain. Yes

6. Gather data: Turn off **Show hurricane**, and click **Reset**. Click **Play**. At 12:00 P.M. of day 1, click **Pause**. From the **Tools** menu, drag a pointer to the predicted position of the eye of the hurricane, and draw an arrow in the diagram below. Label this arrow "1."

Turn on **Show hurricane**, and mark a circle where the actual eye is located. Label this circle "1." Turn off **Show hurricane**, and then repeat this procedure every 12 hours to mark the predicted and actual path of the hurricane.

7. Make connections: As warm, moist air rises, water vapor in the air condenses and releases a great deal of heat energy. This energy powers a hurricane. How does this information explain what happens to hurricanes after they make landfall?

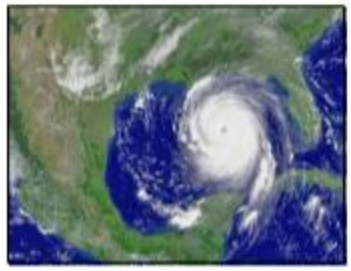
It is getting smaller

Figure B.3: Student 1 Handout – Hurricane Motion Gizmo – Part 3

Virtual Lab (Gizmo): Hurricane Motion

Vocabulary: air pressure, Coriolis effect, eye, hurricane, knot, meteorologist, precipitation

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
A **hurricane** is a large, rotating tropical storm with wind speeds of at least 74 miles per hour. Since 1990, **meteorologists** have regularly used satellite images to track hurricanes.



1. The satellite image at right shows Hurricane Katrina just before it hit New Orleans in 2005. Label the hurricane on the image.

2. How do you think meteorologists predicted the arrival of a hurricane before the 1990s?

   ______the warm weather____

   _

   ____

Gizmo Warm-up
You can use data collected from weather stations to study the characteristics of hurricanes. The *Hurricane Motion* Gizmo has three simulated weather stations. Turn on **Show weather station data**. Make sure **Wind**, **Cloud cover**, and **Pressure** are all checked.

The tails on each station symbol point in the direction the wind is coming from. The flags on the tail indicate wind speed, measured in **knots**. (One knot is equal to 1.15 mph.) A short line extending from the tail indicates 5 knots of wind. A longer line indicates 10 knots. A triangular flag indicates 50 knots. Add all the flags together to get the wind speed.

The number in the station's upper right is the **air pressure**, which is measured in millibars (mb).

The circle symbol indicates the percentage of cloud cover, as shown in the table at right.

Degree of Cloud Cover

Clear	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Overcast
○	⦶	◔	◔	◑	◑	◕	◕	●

Use the information above to complete this table for station **A** on the Gizmo.

Wind speed (knots)	Wind from	Cloud cover	Pressure (mb)
55	north	25%	1007

Figure B.4: Student 2 Handout – Hurricane Motion Gizmo – Part 1

Activity B: **Predict hurricanes**	Get the Gizmo ready: • Select **Experiment** and click **Pause** ( ).	

Introduction: Hurricanes form when an area of low pressure forms over warm water. Winds blow toward the low pressure, but are deflected by Earth's rotation. The **Coriolis effect** causes winds to curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This results in a counterclockwise rotation for Northern Hemisphere hurricanes and a clockwise rotation for Southern Hemisphere hurricanes.

Question: How can you predict the location and path of a hurricane?

1. Observe: Click **Play** ( ), and wait until you see a hurricane approaching one of the weather stations. Click **Pause**. What changes indicate a hurricane is approaching?

   Cloud cover: _____more____________________ Air pressure:bigger ___________________________

   Wind speed: __________add more_________________

2. Observe: Click **Play**, and wait for the hurricane to go over the land. What happens in the hours after landfall? It is getting smaller and smaller____

3. Collect data: Click **Reset** ( ). Turn off **Show hurricane**. Click **Play**. When the simulation reads **Day 1, 3:00 PM**, click **Pause** and record the data from each weather station.

Station	Wind speed (knots)	Wind from	Cloud cover	Pressure (mb)
A	5	north	0	1039
B	0	0	0	1039
C	0	0	On	1039

4. Interpret: Using the readings above, do you think a hurricane is nearby? Explain.

   __no, because they are not low pressure____

   ____

5. Run Gizmo: Allow the Gizmo to run until the weather station data indicates a hurricane is nearby and will soon make landfall. Click **Pause**.

Figure B.5: Student 2 Handout – Hurricane Motion Gizmo – Part 2

A. What weather station data indicated a hurricane would soon make landfall?

___________a____

B. Turn on **Show hurricane**. Was your prediction correct? Explain. _yes , because it was low pressure______________

6. Gather data: Turn off **Show hurricane**, and click **Reset**. Click **Play**. At 12:00 P.M. of day 1, click **Pause**. From the **Tools** menu, drag a pointer to the predicted position of the eye of the hurricane, and draw an arrow in the diagram below. Label this arrow "1."

Turn on **Show hurricane**, and mark a circle where the actual eye is located. Label this circle "1." Turn off **Show hurricane**, and then repeat this procedure every 12 hours to mark the predicted and actual path of the hurricane.

7. Make connections: As warm, moist air rises, water vapor in the air condenses and releases a great deal of heat energy. This energy powers a hurricane. How does this information explain what happens to hurricanes after they make landfall?

___it make the hurricane smaller____

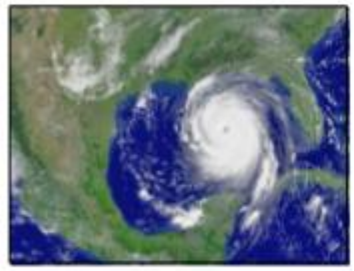
Figure B.6: Student 2 Handout – Hurricane Motion Gizmo – Part 3

Virtual Lab (Gizmo): Hurricane Motion

Vocabulary: air pressure, Coriolis effect, eye, hurricane, knot, meteorologist, precipitation

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
A **hurricane** is a large, rotating tropical storm with wind speeds of at least 74 miles per hour. Since 1990, **meteorologists** have regularly used satellite images to track hurricanes.

1. The satellite image at right shows Hurricane Katrina just before it hit New Orleans in 2005. Label the hurricane on the image.



2. How do you think meteorologists predicted the arrival of a hurricane before the 1990s?

____They could use the barometer.

____

____

Gizmo Warm-up
You can use data collected from weather stations to study the characteristics of hurricanes. The *Hurricane Motion* Gizmo has three simulated weather stations. Turn on **Show weather station data**. Make sure **Wind**, **Cloud cover**, and **Pressure** are all checked.

The tails on each station symbol point in the direction the wind is coming from. The flags on the tail indicate wind speed, measured in **knots**. (One knot is equal to 1.15 mph.) A short line extending from the tail indicates 5 knots of wind. A longer line indicates 10 knots. A triangular flag indicates 50 knots. Add all the flags together to get the wind speed.

The number in the station's upper right is the **air pressure**, which is measured in millibars (mb).

The circle symbol indicates the percentage of cloud cover, as shown in the table at right.

Degree of Cloud Cover

Clear	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Overcast
○	⦶	◔	◔	◑	◑	◕	◕	●

Use the information above to complete this table for station **A** on the Gizmo.

Wind speed (knots)	Wind from	Cloud cover	Pressure (mb)
55knots	NW	25	1007

Figure B.7: Student 3 Handout – Hurricane Motion Gizmo – Part 1

Activity B: Predict hurricanes	Get the Gizmo ready: • Select **Experiment** and click **Pause** ( ).	

Introduction: Hurricanes form when an area of low pressure forms over warm water. Winds blow toward the low pressure, but are deflected by Earth's rotation. The **Coriolis effect** causes winds to curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This results in a counterclockwise rotation for Northern Hemisphere hurricanes and a clockwise rotation for Southern Hemisphere hurricanes.

Question: How can you predict the location and path of a hurricane?

1. Observe: Click **Play** ( ), and wait until you see a hurricane approaching one of the weather stations. Click **Pause**. What changes indicate a hurricane is approaching?

   Cloud cover: ______increase ____________________ Air pressure: _____decrease ______________________

   Wind speed: _____increase _____________________

2. Observe: Click **Play**, and wait for the hurricane to go over the land. What happens in the hours after landfall? _______it looks like it is getting weaker because it got fully black then it got fully white.____

3. Collect data: Click **Reset** ( ). Turn off **Show hurricane**. Click **Play**. When the simulation reads **Day 1, 3:00 PM**, click **Pause** and record the data from each weather station.

Station	Wind speed (knots)	Wind from	Cloud cover	Pressure (mb)
A	30	nw	0	1035
B	10	north	0	1039.2
C	5	north	0	1039.2

4. Interpret: Using the readings above, do you think a hurricane is nearby? Explain.

   ___no because the wind speed isn't even high there is no clouds.____

   ____

5. Run Gizmo: Allow the Gizmo to run until the weather station data indicates a hurricane is nearby and will soon make landfall. Click **Pause**.

   A. What weather station data indicated a hurricane would soon make landfall?

Figure B.8: Student 3 Handout – Hurricane Motion Gizmo – Part 2

_____B was the one that had the hurricane went to____

____

B. Turn on **Show hurricane**. Was your prediction correct? Explain. ___no because the hurricane was not were I thought it would be___________

____

6. Gather data: Turn off **Show hurricane**, and click **Reset**. Click **Play**. At 12:00 P.M. of day 1, click **Pause**. From the **Tools** menu, drag a pointer to the predicted position of the eye of the hurricane, and draw an arrow in the diagram below. Label this arrow "1."

Turn on **Show hurricane**, and mark a circle where the actual eye is located. Label this circle "1." Turn off **Show hurricane**, and then repeat this procedure every 12 hours to mark the predicted and actual path of the hurricane.

7. Make connections: As warm, moist air rises, water vapor in the air condenses and releases a great deal of heat energy. This energy powers a hurricane. How does this information explain what happens to hurricanes after they make landfall?

The hurricane gets weaker because it loses its energy source

____

____

Figure B.9: Student 3 Handout – Hurricane Motion Gizmo – Part 3

Table B.2: Follow-Up Interview from Hurricane Motion Gizmo

Follow-Up Questions	**Student Responses**
What is this gizmo showing? Tell me what you see happening?	Student 1 Response • *"In this gizmo, it is showing a hurricane and weather stations. When the hurricane moves close to a weather station, the wind moves fast. It has low pressure in the hurricane. The barometer at the weather station shows me that"* Student 2 Response • *"It's about the speed of the hurricane. It's showing radar stations with numbers about the speed and strength of the hurricane"* Student 3 Response • *"It shows me a hurricane's motion. It moves counterclockwise. The weather stations show when the*

	hurricane is nearby. The weather station turns black when a hurricane is close"
<u>How does this gizmo help you to understand hurricane motion?</u>	<u>Student 1 Response</u> • *"I can see that whenever it starts, the hurricane is small and gets bigger until it gets to the land, then it gets smaller again"* <u>Student 2 Response</u> • *"Because I can see the numbers changing at the weather stations. I can see where and how the hurricane moves. Being able to see helps me to understand"* <u>Student 3 Response</u> • *"It shows me when it gets to the land and loses its power. It shows me what happens when you move the hurricane to different spots"*

When does the hurricane weaken and why does it weaken?	Student 1 Response • *"Whenever it goes to the land. I can tell that it weakens because the size goes down"* Student 2 Response • *"When the hurricane gets slower. I can see the hurricane going downwards when it weakens"* Student 3 Response • *"It shrinks when it gets to land"*