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Teachers Support for English Language Learners to Build Inquiry Skills in Online Biology Simulations

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Abstract

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MS, Florida Atlantic University, 2006

BS, Florida Atlantic University, 2000

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

The population of English language learners (ELLs) is on the rise in the United States, but they are lagging behind English speaking students in several subject areas—including biology. Scholarly literature lacks information on how biology teachers use scaffolding strategies to support ELL students with inquiry skills during online simulations. The purpose of this qualitative multiple-case study was to explore how biology teachers support ELLs in learning biology, using biology simulations to promote inquiry learning. The conceptual framework for this study included the constructivist perspective regarding the zone of proximal development, Electronic Quality of Inquiry Protocol, and technology use in science instruction. The purposive sample for this study was 4 biology teachers from 2 high schools in large school districts in the southeastern region of the United States who taught ELL students using inquiry-based online simulations. The data sources were face to face interviews with teachers, scaffolding documents, and lesson plans. Data were coded and analyzed for common themes across within and across cases. Results indicated that although biology teachers believed that ELL students benefited from inquiry simulations because of the already incorporated visuals and their ability to interact and manipulate the program, they sometimes lacked technology experiences and struggled with English and literacy that may reduce the benefits of the simulation experiences. The results of this study have the potential to contribute to social change by providing insights that may increase the understanding of how biology teachers can support ELL students when using technology in the form of simulations to promote inquiry learning.

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Dedication

First and foremost, I would like to give glory and honor to Jesus-Christ, my Lord and Savior for keeping me sane through this process. Philippians 1: 6 Being confident of this very thing, that He which hath begun a good work in you will perform it until the day of Jesus Christ.

Acknowledgments

Thank you to my father Roges Joseph for risking your life to give me a better one. Thanks to my mother Tadiste Joseph, who believed in my ability to succeed and encouraged me to continue my education while constantly interceding on my behalf. To my husband, Patrick Orelus (Tchouco), I appreciated you taking our four children to the park to give me time to write. Thanks to my children, Kearsohn, Kharmella, Kherrie, and Kharissa for understanding and enduring the many challenges of this journey. Thanks to the Joseph and Orelus family for not throwing me out of the family when I could not partake in activities to finish assignments. Thanks to Ruth Buchanan, who promised to pray for me and continued to check on me throughout the journey. Thanks to my doctoral committee, especially Dr. Darci Harland, my doctoral chair for all the encouraging words, patience, and guidance. Last, but not least, teachers, I could not have completed this dissertation without your assistance.

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Chapter 1: Introduction to the Study

Inquiry-based learning offers English language learners (ELLs) a comprehensive approach to acquire the language and support science content through thinking skills, questioning skills, and communication skills (Huerta & Spies, 2016; Nargund-Joshi & Bautista, 2016; Ulanoff, Quiocho, & Riedell, 2015; Silva, Weinburgh, & Smith, 2013). In addition, ELL students excel in science when the inquiry-based approach is used with language integration and appropriate scaffolding strategies (Ardasheva, Norton-Meier, & Hand, 2015; Belland, Gu, Armbrust, & Cook, 2013; Buxton & Lee, 2014; Echevarria & Short, 2011; Swanson, Bianchini, & Lee, 2014). ELL students can potentially engage in inquiry-based scientific investigation using virtual simulations to improve learning experiences (Furtak, Seidel, Iverson, & Briggs, 2012; Slavin, Lake, Hanley, & Thurston, 2014; Zhang & Li, 2014). Some researchers have agreed that ELLs cannot learn science without language, but they also suggested integrating language support during instruction to help ELLs succeed in content areas learning (Ardasheva et al., 2015; Buxton & Lee, 2014; Gawne, Wigglesworth, Morales, Poetsch, & Dixon, 2016). Other researchers have proposed using inquiry-based learning to help ELLs learn by doing science (Bergman, 2011) and mimic the methods that real-world scientists employ in scientific research (Bunterm et al., 2014). What is not yet understood is how biology teachers use scaffolding strategies to support ELLs with inquiry skills during online simulations. Thus, the aim of this study was to explore how teachers support ELLs when using online biology simulations to promote inquiry learning.

The population of ELLs in the school system is increasing, and researchers have shown that they lag behind their peers (Callahan & Shifrer, 2016); therefore, having an in-depth understanding of ELLs in biology and how teachers support their educational needs during online biology simulations may be significant in improving practice in the fields of science education, technology in education, and English language learning. It may also contribute to social change. In relation to improving practice in the fields of science and technology in education, the inquiry-based learning approach marshals the core tenets of research, and the recent technological advances provide solutions to practical problems through digital simulation integration to help ELLs grasp complex concepts in biology and make predictions of future biological systems. In addition, computerized simulations remove the barriers of time and space (Zappatore, Longo, & Bachicchio, 2015; Karakasidis, 2013), allowing all students to virtually manipulate scientific equipment not available in the classroom (Heradio et al., 2016) and granting them the freedom to err and learn by repeating simulations as many times as they choose (Zhang & Li, 2014). This process may have unexplored benefits for teachers of ELLs. Furthermore, inquiry-based learning with language integration and appropriate scaffolding strategies provides ELLs with science-content understanding (Ardasheva et al., 2015; Buxton & Lee, 2014). This study may contribute to positive social change because results may inform teacher practices related to language integration in inquiry-based learning to assist ELLs with questioning skills, problem-solving skills, and communication skills. This may, in turn, allow students to question the world around them, develop new insights, and share their explanations with the scientific community.

Therefore, this study was needed not only to advance knowledge in the education field but also to contribute to social change.

Chapter 1 is the introduction to the study. It consists of background information, a summary of research literature, and the research gap. It includes a statement of the problem, the purpose, the conceptual framework, and the central and component questions and related subquestions. It also includes an overview of the methodology of the study, various definitions, the assumptions, the scope and delimitations, and limitations. The chapter concludes with a section on the significance of the research study, its impact on social change, and overall summary leading to Chapter 2.

Background

Although there is a large body of research on ELLs, inquiry-based learning, and technology, the literature review revealed that several gaps exist in what is understood about how science teachers support ELLs when using biology simulations to promote inquiry learning. Researchers have employed several terms throughout the years to define inquiry-based learning, from experiential learning (Dewey, 1938/1997), active learning (Quigley, Marshall, Deaton, Cook, & Padilla, 2011), multifaceted learning (National Research Council, 2013), and student-centered learning (Savery, 2015). Several versions of the inquiry-based learning cycle appear in the science curricula, with phases ranging in number from three to five (Banchi & Bell 2008; De Jong & Lazonder, 2014; Marshall, Horton, & White, 2009; Pedaste et al., 2015). A clear definition of inquiry and how to measure it in the context of this study is important. In this study, I used the definition set forth by the National Research Council (NRC) and the electronic quality of inquiry protocol (EQUIP) model to measure the levels of inquiry.

Several researchers have suggested integration of literacy in inquiry-based learning to support ELLs with understanding science concepts to develop their second-language proficiency with modifications (Carrejo & Reinhartz, 2012; Stoddart, Pinal, Latzke, & Canaday 2002; Zohar & Barzilai, 2013). Other researchers explored the integration of technology in inquiry-based learning (Fullan, 2013; Sox & Rubinstein-Ávila, 2009; Ucar & Trundle, 2011). Researchers have also shown that a significant disparity exists between African American students and ELLs regarding science simulations (Zhang, 2014). The gap that remains is the dearth of research that would explain the extent to which teachers use technology, specifically biology simulations, to support inquiry learning with ELLs.

Additionally, studies on teachers' perceptions of ELLs have addressed how they connect with their pupils (Schall-Leckrone & McQuillan, 2012), training or lack of professional development received (Batt, 2008; Doorn & Schumm, 2013; Hart & Lee, 2003; Pettit, 2011), and their teaching practices (Nargund-Joshi & Bautista 2016). Others acknowledged educators' responsibility in guiding learners during inquiry-based learning to question, analyze data, and derive solutions (Bell, Smetana, & Binns, 2005) and the need to support ELLs via instructional scaffolding strategies using technology (Bransford, Brown, & Cocking, 2000; Belland et al., 2013; Jumaat & Tasir 2014). Though many studies addressed teachers' perceptions of ELLs, Baecher (2012) noted that the training programs targeting instruction for ELLs are minimal. Similarly, the literature on science simulations or virtual labs have ranged from a positive correlation with academic performance (Rutten, van Joolingen, & van der Veen, 2012; Zhang, 2014) to using computer simulations to effectively engage students and fostering deeper learning (Clark, Nelson, Sengupta, & D'Angelo, 2009). Research regarding how best to support ELL students in learning science with simulations is also minimal; several researchers have focused on simulations to assist ELLs with language acquisition (Nemeth & Simon, 2013; Peterson, 2011; Renalli, 2008; Warschauer & Healey, 1998), but their studies do not include teacher perceptions related to teachers using simulations with ELLs.

In this study, I expanded on the current research, attempting to fill the gaps in several ways. First, I expanded on the current research by exploring how teachers use biology simulations to help in fostering inquiry skills in ELL students and whether biology simulations—including the teaching that occurs around the implementation—promote inquiry skills with ELL students. Next, an exploration of the perceptions of teachers of ELLs' strengths and weaknesses during inquiry-based simulations provided understanding regarding how to help ELLs improve scientific literacy and language proficiency. Lastly, studying how biology teachers' scaffolding influences the level of inquiry when using simulations with ELLs and any additional help they provide to ELLs during their lessons expanded on current research by improving practice in the fields of science education. This study is needed in order to contribute to the current research by informing inquiry teaching and learning not only in the fields of science education but also in that of technology in education and English language learning.

Problem Statement

The problem addressed in this study was a lack of understanding regarding how biology teachers leverage online simulations to promote inquiry learning with ELL learners. Educational professionals, policymakers, and stakeholders have endeavored to understand the impetus behind the failing achievement scores of ELLs to make education effective for all students (Elliott, 2015). They have sought to establish equity in education (Coady, Harper, & De Jong, 2015). However, ELL students continue to lag behind in various disciplinary high-stakes assessments (Noble, Rosebery, Suarez, Warren, & O'Connor, 2014). Technological accommodations are incorporated as the most effective to aid assessment developers in making evaluation linguistically accessible (Abedi, 2014). Aside from linguistic, test-taking, and technological accommodations, ELL students need 21st-century skills to be ready for learning, assessments, and their future careers. Learners need analytical skills to investigate, discover, and create; they must have the ability to work with others and solve problems—two key features business leaders look for in their employees (Casner-Lotto, & Barrington, 2006). Students should acquire these skills during inquiry-based learning.

Twenty-first-century skills include creativity, critical thinking, communication and collaboration; these are linked to inquiry learning and technology integration and are vital to students' global literacy (Binkley et al, 2012). However, minorities—specifically ELL students—are not gaining these necessary skills (Murnane, Sawhill, & Snow, 2012). The educational system in the United States discourages the cultivation of these skills with their demands for more assessments (Turnipseed & Darling-Hammond, 2015). In relation to technology integration in inquiry learning, which would include online simulations, a significant disparity also exists between African American students and ELL students regarding science online simulations (Zhang, 2014). Science simulations are positively correlated with high-income and White populations, while negatively correlated to the Black population (Zhang, 2014). Many challenges remain, including how to better prepare ELL students with biological concepts, global competencies, and trans-disciplinary skills such as collaborative and problem-solving skills to close the achievement gap. Another challenge is how to help teachers move students from mere procedural experimentation to inquiry and scientific reasoning in biology classes (Liu & Taylor, 2014). Reviewed literature revealed that science simulations are positively correlated with academic performance (Rutten et al., 2012; Zhang, 2014). Lee and Tsai (2013) analyzed 36 articles dated from 2001 to 2010 based on educational technology and biology using simulations or visualization tools. They reported that many of the articles focused on conceptual outcomes with less emphasis on higher-order skills (Lee & Tsai, 2013). Substantial research exists on simulations for learning science, technology, engineering, and mathematics (STEM) topics and their impact on academic performance; however, the focus has not been on the role of the teacher to better understand the extent to which educators use biology simulations to help in fostering 21st century skills with ELL students. The intent of this study was to increase understanding of how biology teachers incorporate online simulations to promote inquiry learning with ELL students.

Purpose of the Study

The purpose of this study was to explore how biology teachers support ELLs when using biology simulations to promote inquiry learning in biology classes in a large school district in the southeastern region of the United States. To achieve this purpose, in a qualitative case study, I explored the extent to which inquiry is implemented within biology simulations lessons in relation the four levels of the EQUIP model (see Marshall et al., 2009). I also explored how teachers use the integration of technology in science pedagogy, and the usefulness of technological integration in biological simulations using the technology use in science instruction (TUSI) as developed by Campbell and Abd-Hamid (2013) and the constructivist theory (Vygotsky, 1978), specifically the zone of proximal development (ZPD). Additionally, in this study, the EQUIP and ZPD were used to examine the perceptions of teachers on the strengths and weaknesses of ELLs concerning inquiry instruction and their descriptions of the instructional support of ELLs during the implementation of biology simulations.

Research Questions

The research questions for this study were based on the conceptual framework and literature review.

Central research question: How do biology teachers support ELL students when using online biology simulations to promote inquiry learning?

Component questions and related subquestions:

1. How do teachers perceive ELL students' strengths and weaknesses in relation to inquiry learning using simulations?

2. How does teacher scaffolding influence the level of inquiry for ELL students?

    2.1. How do teachers describe their scaffolding to support ELL students' inquiry learning during the implementation of biology simulations?

    2.2. How do teachers use scaffolding in online simulations to make scientific inquiry understandable to ELL students?

    2.3. What level of inquiry do teachers address in biology simulations for ELL students based on the indicators of the EQUIP framework?

Conceptual Framework

The conceptual framework for this study included one theory and two models. First, the study was based on the theory of constructivism (Schunk, 2012; Vygotsky, 1978). Constructivism presupposes that learning is an active process in which individuals construct knowledge for themselves (Schunk, 2012; Vygotsky, 1978). It also aims to promote critical thinking, comprehension, and use of gathered information, self-regulation, and reflection (Driscoll, 2005). It is student-centered and entails active learning (Mayer, 2005). The constructivist perspective is synonymous to the inquiry-based learning approach, which demands high-order thinking capabilities where students ask scientific questions, design procedures, connect explanations to scientific knowledge, communicate, and justify the answers (Quigley et al., 2011; Zion & Mendelovici, 2012). The crux of the theory is how the human brain understands and constructs knowledge. In constructing knowledge, students are allowed to reach their ZPD through social interaction. Wertsch (2008) indicated that the ZPD refers to the range of performance that a learner can perform with assistance but cannot yet accomplish independently.

Through scaffolding, teachers can afford learners opportunities to acquire critical thinking skills such as problem-solving and collaboration to support ELLs in learning biological concepts. The second component of the conceptual framework for this study is the EQUIP, which was developed to gauge the extent to which teachers implement inquiry in their lessons (Marshall et al., 2009). EQUIP includes four levels to describe inquiry: preinquiry, developing inquiry, proficient inquiry, and exemplary inquiry (Marshall et al., 2009). EQUIP is a highly reliable and valid instrument used to assess the quality of inquiry during instruction (Smart & Marshall, 2013; Marshall, Smart, & Horton, 2010). This protocol was used to measure the level of inquiry of the biology simulations themselves as well as the supplementary resources or teaching practices that might change the level of inquiry students' experience. TUSI was the third component of the conceptual framework. Campbell and Abd-Hamid (2013) developed this analytical instrument to assess the integration of technology in the science pedagogy. In addition to exploring the extent to which technology is useful for science teaching and learning, it was used as a tool for evaluating educators' knowledge of technology as it relates to their practices and standards alignment. TUSI was used to determine the alignment and usefulness of the integration of technology in biological simulations.

The constructivism theory, EQUIP, and TUSI models aided in the development of instruments used for data collection. First, I used the conceptual framework to develop the interview questions. Interview questions were developed using the constructivist theory and the two models mentioned. EQUIP and ZPD aided in developing questions related to how teachers perceive ELL students' strengths and weaknesses concerning inquiry instruction, and how they describe their instructional scaffolding strategies to support ELL students during the implementation of biology simulations, which relate to Component Research Questions 1 and 2. Second, to develop instruments for document data collection of the Subquestions 2.2 and 2.3, both TUSI and EQUIP models were used. EQUIP offers an efficient protocol to rate the quality of inquiry-based biological simulation instruction in the science classroom (Marshall et al., 2009). The TUSI model helped in organizing and viewing themes that emerged from the online simulations as well as from the scaffolding documents teachers use in conjunction with the simulations since this model helps determine the level to which technology is integrated into science pedagogy (Campbell & Abd-Hamid, 2013). Therefore, both EQUIP and TUSI were used to develop organizational tables related to the levels and quality of inquiry to help organize data collected about the biology simulations and the instruction that surrounds the online simulation.

The instruments developed using the conceptual framework also aided in the data analysis. Data gathered from multiple sources, teacher interviews, scaffolding resource documents, and the software simulation were analyzed based on conceptual framework developed from the constructivism theory, EQUIP, and TUSI models. The analysis was completed at two levels. First, single cases were analyzed through coding and categorization. At the second level, cross-case analysis was conducted to identify emerging themes and discrepancies. The emerging themes helped to facilitate interpretations and relationships, which served to inform the key results of the study. The conceptual framework and its connection to this study are addressed in more detail in Chapter 2.

Nature of the Study

For this qualitative study, I used the multiple case study design. Yin (2014) defined a case study in two parts. The two parts are the scope and key features. In terms of scope, case study is a pragmatic study that entails exploring a phenomenon in depth and within its context, especially when the link between the case and the context is not apparent. In terms of key features, case study offers researchers the opportunity to triangulate and converge multiple sources of data (Yin, 2014). A case study strategy permitted me to examine the context and setting to offer a more in-depth understanding of the topic under study (see Stake, 1995; Yin, 2014). Yin also noted that the case study is used to further the knowledge of a group or related phenomenon and allow the researcher to answer how and why questions of the study. Moreover, according to Baxter and Jack (2008), a case study allows researchers to explore a phenomenon within its framework using diverse data sources within its context. For this study, the phenomenon under investigation was how biology simulations might foster inquiry skills with ELL students. The case or unit of analysis is defined as the area of focus of the study (Merriam & Tisdell, 2016; Yin 2014). For this study, the unit of analysis was the individual high schools in the southeastern of the United States. Choosing a high school as a case satisfied the purpose of the study, which was to explore how biology teachers support ELLs when using biology simulations to promote inquiry learning in biology and answer the research questions. Selecting each teacher or classroom as a case generated several behavioral variables to analyze. I was also limited in resources and time to conduct a multiple-case study that would produce a large amount of data. Furthermore, selecting each teacher or classroom would not satisfy the purpose of this study. A sample of four teachers from two high schools who have implemented biology simulations were selected for this multiple-case study. Participants were biology teachers who have ELL students. These ELL students are monitored by the English to speakers of other languages (ESOL) coordinator at the school. Data were collected from multiple sources, including teacher interviews, lesson documents, and the online simulation. Data were analyzed at two levels. First, each case was analyzed through coding and categorization. Next, cross-case analysis was conducted to identify emerging themes and discrepancies to inform the key findings of the study (see Merriam & Tisdell, 2016). A multiple-case study of two high schools provided a deeper understanding of the phenomenon being studied, rather than drawing comparability and similarities among four individual teachers.

Definitions

Computer simulations: These programs run on a computer and use detail methods to study approximate mathematical models of the hypothetical or real-world system, including animations, visualizations, and interactive laboratory experiences (Bell et al., 2005; Winsberg, 2015).

Developing inquiry: This type of inquiry entails active engagement with open-ended discussions, and teachers still facilitate and disseminate knowledge (Marshall et al., 2009; Quigley et al., 2011).

English language learners: Abbreviated as ELLs, these students have yet to acquire the English language and communicate their learning fluently and more efficiently. They usually need modified instruction to achieve success in academic language courses (Abbott, 2014).

Exemplary inquiry: This level of inquiry is student-centered. Students construct an understanding of content, and teachers facilitate learning through encouragement in developing concepts and challenging misconceptions (Marshall et al., 2009; Quigley et al., 2011).

Inquiry-based instruction in science: Inquiry instruction is a multifaceted activity and involves making observations; posing questions; examining books and other sources of information to see what is already known considering experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 2013).

Next generation science standards: Abbreviated NGSS, these K to 12 science standards set the expectations for what students should know and be able to do. The standards were developed by states to improve science education for all students (NGSS Lead States, 2013).

Preinquiry: This type of inquiry is teacher-centered. It is prescriptive, with no attempt at the inquiry process (Marshall et al., 2009; Quigley et al., 2011).

Proficient inquiry: In this stage, students are actively engaged and guide the inquiries (Marshall et al., 2009; Quigley et al., 2011).

Scaffolding: This instruction figure provides active support to aid learners in engaging with an assignment that they could not perform without help (Belland et al., 2013).

Zone of proximal development (ZPD): This term refers to the range of performance that a learner can reach with assistance but cannot yet accomplish independently (Wertsch, 2008).

Assumptions

This study was centered on two assumptions. The first was that scaffolding resource documents and online simulations used for analysis would be accurate and effective in obtaining information about the phenomenon. This assumption was important to the study because these documents served as supporting evidence regarding how or if inquiry learning experiences for ELLs are scaffolded within this case study. The second assumption was that in interviews, study participants would answer the questions in an honest and candid manner in describing their instructional support of ELLs during the implementation of biology simulations. I also assumed that they would respond honestly on how they perceive the strengths and weaknesses of ELLs concerning inquiry-based learning. This assumption was also relevant to the study because the perceptions of these participants affect their pedagogical practices.

Scope and Delimitations

The scope of study refers to the parameters, which were two public high schools within the school districts. The research problem related to this study was how biology teachers use online simulations to promote inquiry learning with ELL students. Substantial research already existed in the education field, but very little was known about the extent to which educators use biology simulations to help in fostering 21st-century skills like problem-solving and collaboration with ELL students. The scope of this study related to this problem was focused solely on how biology teachers use online simulations to promote inquiry learning with ELL students. It was relevant to focus on understanding this problem because many challenges remain, including how to better support ELL students in their learning of biological concepts and in practicing collaborative and problem-solving skills. The two public school districts used in this study are culturally and racially diverse and have several high schools, middle schools, and elementary schools. One school district serves 193,000 students, while the other has a population of 271,517 students. Two high schools were selected from all the high schools that had students who are enrolled in Biology from Grade 9 to 12 and had ELL students.

This study was also bound by its purpose, which was to explore how biology teachers support ELLs when using biology simulations to promote inquiry learning in biology courses in the school districts in the southeastern region of the United States. The study did not address simulations or inquiry learning done outside of biology. The conceptual framework defined the scope of the study. Using the constructivist perspective alone would not have provided sufficient information to understand the phenomenon. Therefore, developing a conceptual framework that merged the constructivist theory, specifically the ZPD with the EQUIP and TUSI, bound the study to the exploration of the levels of inquiry in biology online simulations and teachers' support of ELLs in their inquiry learning experiences. This was directly relevant to the central research question, component questions, and the related subquestions of the study.

The delimitations of this study involved the resources, the time, and the selection of participants. In relation to time and resources, this study was narrowed by time and resources, since I was the sole researcher. Furthermore, the study was limited in terms of participants to teachers with 2 or more years of teaching biology who had ELLs and used inquiry-based online simulations. Therefore, all other science teachers were excluded from the participant pool. This sample improved the transferability of the study because according to Merriam and Tisdell (2016) and Miles, Huberman, and Saldana (2014), by using rich, thick description, the researcher provides exhaustive descriptions of the setting, participants, and findings of the study.

Limitations

The case study qualitative research design has inherent limitations, such as subjectivity and lack of reliability, validity, and generalizability. Yin (2014) noted that a small sample size is problematic in generalizing the findings for qualitative studies. In addition, the case study strategy is limited by sensitivity and integrity of the researcher.

Merriam and Tisdell (2016) warned that a researcher might exhibit bias by discounting data that challenge the researcher's previous experiences and beliefs. As a science teacher who taught biology for several years at two rural school districts, I might have expressed potential bias. Therefore, since I was the primary collector of data and the sole analyst, I employed the strategies recommended by Merriam and Tisdell (2016), Creswell (2013), and Yin (2014). These strategies included making "analytic generalization" by expanding theories (Yin, 2014, p. 40), assuring validity and reliability by using three sources of evidence and the case study protocol and triangulating to address potential researcher's bias. These strategies are covered more explicitly in Chapter 3.

Significance

The significance of this study is determined in relation to (a) the level of innovation (b) advancing knowledge in the education field, (c) improving practice in the fields of science education, technology in education, and English language learning, and (d) contributing to positive social change. In relation to innovation, this study was innovative since simulations were explored regarding inquiry science teaching as a novel approach to determine if ELLs are being exposed to inquiry learning. Concerning the advancement of in the field of education, this study may increase the understanding of whether biology simulations and the teaching that occurs around the implementation foster problem-solving with ELLs. In relation to improving practice in the field of education, the outcomes of this study may offer education professionals options regarding the implementation of biology simulations to aid ELL students in acquiring inquiry skills in innovative ways. Furthermore, insights from this study may provide science educators with supplemental approaches for implementing simulations that not only help students understand biological concepts but also provide students practice in scientific inquiry skills. The increased understanding of teachers' experiences using inquiry-based biology simulations has the potential to stimulate positive social change since science teachers may be able to become more intentional in how they support ELL students' development of collaboration and problem-solving skills. Last, this study is significant because it may provoke positive social change. As teachers find new strategies to support ELLs, it may help to close the educational achievement gap of the underprepared ELL population to prepare them better for the workforce.

Summary

Chapter 1 included an overview of the study. It included the background and the problem statement regarding inquiry-based biology simulations and ELLs. This introductory chapter contained the purpose of the study, which was to explore how biology teachers support ELLs when using biology simulations to promote inquiry learning in three high schools in a large urban school district in the southeastern region of the United States. I also explained that the EQUIP model (Marshall et al., 2009), the TUSI model (Campbell & Abd-Hamid, 2013), and the ZPD (Vygotsky, 1978) were used to assess the levels of inquiry and develop interview questions as indicated in the central, component questions, and related subquestions. Additionally, I described the nature of the study as a case study, the relevant definitions, assumptions, scope and delimitations, limitations, and the significance of the study and as related to social change. A synthesis of the literature review concerning this study is described in Chapter 2.

Chapter 2: Literature Review

The purpose of this study was to explore how biology teachers support ELLs when using biology simulations to promote inquiry learning in biology. I completed a comprehensive literature review to achieve saturation on the proposed topic. Using terms such as *English language learners* (ELLs), *inquiry-based learning*, and *simulations* helped start the literature search of this study. Exploration with these terms yielded definitions and results from several researchers regarding ELLs, inquiry-based learning, and simulations. ELL students are recognized as the fastest growing group of students in the United States (Fayon, Goff, & Duranczyk, 2010), and they are estimated to make up roughly 40% of the student population by the year 2050 (Ardasheva et al., 2015). Though the number of ELLs in the United States has increased dramatically, the disparity in achievement scores persists (Callahan & Shifrer, 2016). Studies on inquiry-based learning with ELLs have yielded positive results when language is integrated (Ardasheva et al., 2015; Buxton & Lee, 2014; Tong, Irby, Lara-Alecio, & Koch, 2014). In addition, the literature that I reviewed showed that science simulations are positively correlated with academic performance (see Lee & Tsay, 2013; Rutten, van Joolingen, & van der Veen, 2012; Zhang, 2014). However, very little is known about the extent to which teachers use biology simulations to help ELLs foster inquiry skills. The aim of this study was to increase understanding of how biology teachers use online simulations to promote inquiry learning with ELLs.

The problem addressed in this study was a lack of understanding regarding how biology teachers use online simulations to promote inquiry learning with ELLs. The literature review was expanded using additional terms mentioned in Table 1 of the literature search strategy. Chapter 2 includes a synthesis of the literature review related to the purpose and problem of this study. First, it contains the iterative search process for the literature search strategy. Next, I describe the development of the conceptual framework, its application in previous research, and its benefits to the current study. In addition to the synthesis of the literature, the last section of Chapter 2 also contains what remains to be explored, a summary of the major themes of the literature review, and the gaps in research, which this study may help to fill.

Literature Search Strategy

The literature review required an exhaustive search. I conducted a search using the Walden University Library website and Google Scholar. Employing several databases, such as Education Resource Information Center (ERIC), Education Search Complete, Sage Journals, and Science Direct, I conducted a search using key terms from the study. The following keywords were included in the primary search using the Google Scholar website: *English language learners, inquiry-based learning, biology,* and *simulations*. Searches containing these keywords yielded results linked to the Walden University Library. Articles from the Walden University Library had to be limited to the past 5 years, which led to additional key terms included in Table 1. Articles from these searches were organized in themes, which provided the background and a synthesis of literature review for this study.

Table 1

Research Themes and Keywords Search

Research themes	Keywords search
English language learners	*basic interpersonal communication skills (BICS), cognitive academic language proficiency (CALP), comprehensible input, English for speakers of other languages (ESOL)*
Inquiry-based learning	*5E model, problem-based learning, 21st-century skills, thinking skills, questioning skills, collaboration, levels of inquiry, Dewey, constructivism, hands-on*
Instructional support	*Scaffolding, modified instruction, interaction, sheltered instruction observation protocol (SIOP), small group, collaboration*
Simulations	*technology, virtual labs, technological pedagogical content knowledge (TPCK), computer-based, online simulated labs*
Teachers' perceptions	*diversity, beliefs, individual experiences, training, instructional practices*

To achieve the level of saturation needed for this study, additional searches were conducted using keywords from the acquired articles in the Walden University Library. Rather than using inquiry-based learning and simulations, I completed a search in the Education Search Complete database with the keywords *21st-century skills* and *technology* that yielded 310 articles. When vetted for relevance and selected peer-reviewed, 188 articles were available for review. I continued to narrow these items to academic journals, which reduced them to 183, and to 143 within the past 5 years.

Selecting articles related to problem-solving from the list provided 12 articles within the theme of inquiry-based learning and 31 articles on technology related to the simulations theme. The process continued with more keywords from Table 2, providing a substantial number of articles that I analyzed for relevance in establishing additional themes. Using this iterative process, I acquired an adequate number of articles to make me confident that I had reached saturation.

Conceptual Framework

The conceptual framework for this study was grounded in Vygotsky's (1978) constructivism perspective on the ZPD (Marshall et al., 2009), EQUIP model, and Campbell and Abd-Hamid's (2013) TUSI. Vygotsky asserted that exposing learners to more opportunities to foster academic and social skills in collaborative learning environments with others will afford them a milieu to cultivate their academic and social skills. The EQUIP model was used to measure the level and quality of inquiry in science instruction (Marshall et al., 2009). The TUSI model provided an approach to assess the integration of technology in science teaching and instruction (Campbell & Abd-Hamid, 2013). The theory and two models above provided the basis to study how biology teachers use simulations to promote inquiry learning with ELL students.

Constructivism

Constructivism presupposes that learning is an active process in which individuals construct knowledge for themselves (Schunk, 2012; Vygotsky, 1978). In creating knowledge, learners can reach their ZPD through social interaction. Wertsch (2008) indicated that the ZPD refers to the range of performance that a learner can perform with assistance but cannot yet accomplish independently. According to Vygotsky (1978), teachers can understand students' cognitive skills when they evaluate the learners' talents within their social construct. Vygotsky claimed that learners socially create knowledge in collaboration with others. Vygotsky also posited that students' cultural backgrounds and experiences impact learning and development. Learners' ZPD varies as they learn and acquire new skill sets. Educators can help students improve their cognitive development by assessing their students' aptitude to construct challenges within their ZPD.

Constructivism, specifically Vygotsky's (1978) ZPD, was used to inform this research in helping to better understand how biology educators use simulations to foster inquiry instruction with ELLs. The theory was used in this study to develop instruments to collect data. First, the conceptual framework helped in the development of interview questions. Interview questions related to how teachers perceive ELL students' strengths and weaknesses concerning inquiry instruction and how they describe their instructional support of ELL during the implementation of biology simulations, which relate to Component Questions 1 and 2. Teachers can help ELLs attain competency by allowing students to use cognitive skills their cultures afford and through collaboration with more proficient students. Teachers are in a position to pinpoint how their teaching is most beneficial to ELL learners and what students can achieve on their own. Interview questions based on Vygotsky's (1978) ZPD may help focus on this element of teaching as data were collected on biology teachers' perceptions of ELL students' strengths and weaknesses in relation to inquiry learning and how they describe their instructional support of ELL students during the implementation of biology simulations.

EQUIP Model

The EQUIP was the second component of the conceptual framework for this study. The protocol was developed to gauge the extent inquiry is implemented within the classroom (Marshall et al., 2009). EQUIP includes four levels to describe inquiry: preinquiry, developing inquiry, proficient inquiry, and exemplary inquiry. This protocol is used to assess the quality of inquiry that takes place throughout the learning process (Marshall et al., 2009; Quigley et al., 2011). Preinquiry is teacher-centered and prescriptive with no attempt at the inquiry process (Quigley et al., p. 56) Developing inquiry entails active engagement with open-ended discussions, and teachers facilitate and disseminate knowledge (p. 56). Students are actively engaged in the learning process, and inquiries are guided during the proficient inquiry (p. 56). Exemplary inquiry is student-centered, during which time students construct an understanding of content, and teachers facilitate learning by encouraging students to develop concepts and challenge misconceptions (Quigley et al., 2011). The EQUIP instrument can be used to measure four core factors that support the inquiry process in teaching and learning. The five factors are as follows: time usage, instruction, discourse, assessment, and curriculum. Each factor is measured using the four levels of inquiry.

Time usage. The time usage factor can be used to assess level of inquiry at the beginning of a lesson while the other four can be evaluated at the end of the lesson (Marshall et al., 2009, p. 51). The time usage factor comprises activity focus, which an educator facilitates organizational structure; student attention; and the cognitive levels of the learners. It includes five different indicators, from noninstructional time to measuring exemplary inquiry. Students can work individually, in a small group or whole as part of the organizational structure feature. Student attention ranges from low, medium, or high regarding the level of engagement in the lesson. The last indicator is the cognitive level. It entails looking at students' performance during instruction from low order to high order processing (Marshall et al., 2009, p. 47).

Instruction. The second factor is associated with instruction. The measured constructs include the instructional strategies, the order of the instruction, teacher role, student role, and knowledge acquisition (Marshall et al., 2009, p. 51). Each of these indicators is measured using Level 1 preinquiry up to Level 4 exemplary inquiry. For example, if the teacher is predominately lecturing while covering the content during the instruction, that would be Level 1 or preinquiry However, if the teacher is occasionally talking but the students are engaged in investigations that promote strong conceptual understanding, that instructional strategy would be scored at the exemplary level. Another example would be the role of the teacher and its significance to instruction. A teacher at the center of the lesson would be at the preinquiry level, but at the exemplary level, the teacher would consistently and more efficiently facilitate instruction (Marshall et al., 2009, p. 48).

Discourse. The discourse factor is utilized to measure the classrooms' environment and the students' interactions in connection to inquiry instruction and learning (Marshall et al., 2009, p. 51) The constructs measured are the questioning level, questions complexity, questioning ecology, communication pattern, and classroom interactions. For example, in looking at questioning ecology, if a teacher lectures or engages students with oral queries that do not lead to more discussions, that is a preinquiry level 1. On the other hand, if a teacher efficiently engages the students in open-ended questions that lead to discussions in which they can investigate and reflect on their learning, that is indicative of the of level 4 exemplary inquiry (p. 49).

Assessment. Assessment factors also have five indicators that are used to measure the instructional practice in relationship to the instructional practice (Marshall et al., 2009, p. 52). The five indicators are as follows: prior knowledge, conceptual development, student reflection, assessment type, and the role of assessing. In regard to the role of assessing, a teacher can solicit predetermined answers from students requiring little explanation or justification for the responses. That would be preinquiry at Level 1. Then again, a teacher who frequently and consistently assesses student understanding and adjusts his/her instruction accordingly to challenge the students to provide more evidence based on the claims and encourages their curiosity and openness would be working at the exemplary inquiry level. Another example is the assessment type in which students receive factual and discrete knowledge at Level 1, but at Level 4 their formal and informal assessments are consistent, authentic, and measure what was supposed to be measured (Marshall et al., 2009, p. 50).

Curriculum. The last factor is the curriculum factor. This factor has four indicators that can help educators in measuring issues associated with curriculum issues that may impact inquiry instruction (Marshall et al., 2009, p. 52). It includes standard organization and recording of information. Standards drive pedagogy; therefore, if the curriculum includes that information, it will assist the educators in measuring the level of inquiry within the curriculum. The other two indicators are content depth and learner centrality. Purposely creating lessons with explicit connections and incorporating the flexibility for students to design and execute their investigations are indicative of exemplary inquiry (Marshall et al., 2009, p. 51).

The EQUIP model has been used in a variety of ways. Gormally, Sullivan, and Szeinbaum (2016) used the EQUIP to assess inquiry instruction of new biology teaching assistants (TAs). After completing a preparatory course on teaching strategies that included a unit on inquiry, the researchers used the model to evaluate the TAs' inquiry pedagogical practices based on the four categories: instruction, discourse, assessment, and curriculum. Their findings revealed three areas that need improvement *vis-à-vis* inquiry teaching. First, TAs need to develop facilitation skills for inquiry instruction. Second, they need to relinquish responsibility and control to the students during the learning process, allowing them to learn from their failures. Last, they need to know that positive student evaluation comments should not deter their pursuit of the inquiry-based practices. Their findings indicate that professional development and continuous evaluation of inquiry instruction could be beneficial in science instruction with a shift from teacher-centered to student-centered learning. Some inquiry-based professional development has been shown to be unsuccessful in supporting teachers with transforming their teaching practices (Gormally et al., 2016).

The model has also been used to measure inquiry within technologically integrated lessons. Henderson-Rosser (2015) utilized the EQUIP model in a qualitative case study to assess inquiry-based instruction in science and math classrooms in her doctoral dissertation on How Do Teachers Utilize iPads to Enhance the Quantity and Quality of Inquiry-Based Pedagogy within STEM Classrooms. Sixth, seventh, and eighth-grade science classes were observed using the EQUIP model. The results showed inquiry instruction at the Developing level, but technology helped with the implementation of inquiry instruction; however, it did not reveal high levels of inquiry pedagogy. Her results supported the notion that technology is integrated to enhance already occurring inquiry instruction and that technology-based strategies are needed to support collaboration and active learning to achieve exemplary inquiry level. Technology is used to enhance the teachers' role during inquiry-based learning to guide learners reflect on the relatedness of the tool to the scientific concept to arrive at exemplary inquiry.

Oppong-Nuako, Shore, Saunders-Stewart, and Gyles (2015) found the EQUIP as a useful tool to measure the degree of inquiry in science and math. However, they used the rubric developed by Llewellyn (2004) with 12 categories of Low and High Inquiry, which was later modified by Saunders-Stewart, Gyles, Shore, and Bracewell (2015). Marshall et al., (2009) also mentioned rubric in developing the EQUIP model (p. 47). Using the modified model, Oppong-Nuako et al., (2015) evaluated interviews from 6 teachers of 14 secondary classes. Educators responded to questions about their teaching, learning techniques, use of inquiry-based strategies, and classroom descriptions. They were asked about their typical school day, student expectations, and inquiry instruction results. The EQUIP model is used to evaluate inquiry instruction; therefore, in the Oppong-Nuako et al., study, the Llewellyn model afforded the researchers with results on teachers' daily routines and students' expectations. In regard to inquiry, they sought to gather information on teachers who used most, middle, and least Inquiry with a modification. This approach provided a relatively straightforward method to assess the extent of classroom inquiry implementation. However, the EQUIP model provides a thorough breakdown of five components with various indicators to measure levels of inquiry with science instruction which is why it was chosen as part of the framework for this study.

Radišić and Jošić (2015) also employed EQUIP to examine the level inquiry in two math classroom recordings. In their study, they used the order of instruction indicator to follow the progression of teaching; and under the discourse construct, they focused on communication patterns and classroom interaction pattern. Also, as part of the time usage, they selected to use indicators measured at five-minute intervals that were central to their study: Cognitive Level of students and Component of Inquiry. Their results revealed negligible difference between the classes regarding time usage. However, differences were found for the components developing inquiry: more time was spent in one class and proficient-exemplary inquiry activities in the other class. Regarding Components of Inquiry, no differences were found between the two classrooms. Their research showed that the EQUIP model could be used in its entirety or partly to assess a specific areas of inquiry instruction. EQUIP could be used in a variety of ways to evaluate inquiry-based learning to improve instructional practices.

The EQUIP model was used in this study to develop instruments for document data collection on the levels of inquiry that are evident in the online biology simulations. The EQUIP model offers five factors with distinct indicators that I used to measure the levels of inquiry in biology simulation lessons that educators select to teach ELL students. It was also used to analyze lesson documents used during instruction before the simulations, support provided during, and any support that the teacher offers the students after the simulations. Additionally, the model was used to craft interview questions to better understand how teachers perceive ELL students' strengths and weaknesses concerning inquiry instruction, including how they describe their instructional support of ELL during the implementation of biology simulations. Some components of the EQUIP model, time usage, instruction, and discourse were used during the simulated lesson; however, assessment and curriculum were used during data analysis of lesson documents from the teachers.

TUSI Model

Campbell and Abd-Hamid (2013) designed the TUSI model as a tool to measure how technology enhances the effectiveness of science instruction. The design offers educators a lens through which to conceptualize their implementation and use of technology in their lessons. It also allows them to determine the extent to which their technological infusion of instruction aligns to national science standards. The authors utilized two main documents to support the role of technology in science and vice versa:

Science for All Americans and the *National Science Education Standards*. Also, they relied on the technological pedagogical knowledge (TPACK) of Koehler and Mishra (2008) and the five guidelines from Flick and Bell (2000) to develop their model. The following five guidelines ensure alignment to the science standards and ensure that technology does not alter instruction (Campbell & Abd-Hamid, 2013, p. 575):

1. Technology should be presented in the context of science relevancy.
2. Technology should address meaningful science with appropriate instruction.
3. Technology pedagogy and science should take advantage of the unique features of the technology.
4. Technology should make scientific views more comprehensible.
5. Technology pedagogy should extend students' understanding of the connection between technology and science.

The researchers provided a completed TUSI instrument with observation guide consisting of the five guidelines with five to six indicators to rate instruction on a scale of zero to four within each guideline. For example, a score of zero indicates that the observer did not see direct application of the directive, while a score of four demonstrates that the guideline was descriptively observed. The guide provides examples and clarifications for classroom technological and pedagogical application.

Instruction. The first two and the last components of the TUSI model focused on instruction. First, technology should be presented in the context of relevance to science, which denotes that educators should link the technology to students' aspirations to learn the content (Campbell & Abd-Hamid, 2013, p. 583). The technology should be used to support the learner's curiosity to engage in scientific investigations, gather meaningful data, and support the advancement of skills acquisition. Also, students use technology as a tool to understand natural phenomena. Second, technology should address relevant science content with appropriate instruction signals student-centered, inquiry-based learning. Technology is used to foster high-order thinking, facilitate the conceptual development of scientific nous, and empower learners to delve into the learning process. Also, as a tool, technology affords students a way to collaborate and construct their scientific inquiry knowledge of the nature of science from developing questions to formulating conclusions. The third and final component of the model relating to instruction is that technological education should improve students' understanding of the connection between technology and science. With that in mind, teachers need to develop lessons that use technology to increase scientific literacy.

Technology. The two indicators concerning technology are as follows: technological pedagogy in science should take advantage of the unique technological features available, and technology should make scientific views more accessible (Campbell & Abd-Hamid, 2013, p. 585). Technology enhances the teachers' role but does not replace it. Educators can utilize it to help students explore scientific topics more in depth and make complex and abstract content more comprehensible. Also, they can use technology to extend instruction, significantly enhancing the learning experience; without it, the learner would not attain the desired effects. Harmony exists between technology and hands-on laboratory experiences. Scientific views can be accessible with technology through models and visual representations. Technology offers learners opportunities to simulate the conceptual part of a phenomenon; however, teachers need to ensure that students connect the simulated phenomenon to the experience of the actual event observed. Through discussions and reflections, learners could differentiate between computer-simulated and real events and significance in constructing scientific knowledge.

Technology is shaping and reshaping how students learn; educators are entrusted to prepare them to use it to solve scientific and societal problems. Technology integration benefits both teachers and students (Campbell, Longhurst, Wang, Hsu, & Coster, 2015). Campbell et al., (2015) utilized the Reformed Teaching Observation Protocol (RTOP) and Technology Use in Science Instruction (TUSI) instruments to assess educators' instructional practices. They investigated the influence of professional development project that centered on improving teacher and student knowledge with information and communication technologies (ICTs) for attracting students in reformed-based instruction. They reported on the optimistic teacher outcomes *vis-à-vis* reformed-based and technology integration in education. Their findings revealed that both educators and students showed positive results to ICT and literacy skills, demonstrating that all students could benefit from educators' participation in professional development. Furthermore, the study showed how technology could serve as a tool to improve teachers' roles and allow them to enhance the quality of their inquiry instructional practices.

The TUSI model also helped frame this study. It offers five categories with indicators. Three of the five focus on the use of technology in teaching. However, the other two indicators of the TUSI model supply the tool to evaluate educators' knowledge of technology as it relates to their technology practices and standards alignment. All five categories of the TUSI model were used in data collection and data analysis. It was utilized as an instrument to gather data on how technology is used in science instruction and in developing interview questions related to the levels and quality of inquiry to help organize data collected on biology simulations and the teaching that surrounds the online simulation. During analysis, it helped to organize data and recognize themes that emerge from the online simulations as well as from the documents teachers used in conjunction with the simulations. The model was used to determine the alignment and the level of which technology was incorporated in biological simulations lessons (Campbell & Abd-Hamid, 2013).

This study was framed by Vygotsky's (1978) constructivism perspective on the Zone of Proximal Development (ZPD), Marshall et al. (2009) Electronic Quality of Inquiry Protocol (EQUIP) model, and Campbell and Abd-Hamid's (2013) Technology Use in Science Instruction (TUSI) model. The constructivist perspective helped with interview question development concerning the cognitive performance and strategies used to help ELLs arrive at their ZPD. In addition to interview questions, the EQUIP and TUSI models were utilized in data collection and analysis regarding inquiry learning and technology integration. Using scholarly literature support on the constructivist paradigm on learning through social interaction to achieve ZPD and the two models, this study added to the growing body of knowledge on inquiry instruction and contributed to understanding how biology teachers use simulations to foster inquiry learning with English Language Learners.

History of Inquiry-Based Science Pedagogy

Several theorists contribute to understanding inquiry-based learning to enhance students' science instruction and critical thinking skills. Three of the most notable educational contributors are Dewey, Piaget, and Vygotsky. Starting in the late 19th and early 20th centuries, John Dewey emphasized and urged science education through student experiences (Dewey, 1938/1997). Dewey's views on inquiry suggested a new "pattern of organization" in science education. He advocated for learners by contrasting traditional and progressive education: he instructed educators to use their students' experiences rather than teaching repetitious facts to prepare them for their future endeavors and success in life (Dewey, 1997, pp. 17-23). He noted that by understanding students' experiences, education professionals could design genuine and organic curriculum that would benefit both individual students and society at large (pp. 25-31). Overall, Dewey's approach emphasized preparing students to become contributing members of society, which required a change from traditional learning to experiential learning or inquiry-based learning. Piaget agreed that whenever new information is acquired, learners need instructional tasks that challenge their prior experiences and spur them to modify their understanding (Piaget, 1977). He underscored the importance of teaching through discovery by providing students with tasks that challenge their abilities and use existing experience (Piaget, 1952). He viewed inquiry as an entrenched quality within the individual child, who formulates knowledge through hypothesizing and testing his or her experiences of the natural world (Cole & Wertsch, 1996). He suggested that scientific concepts are not fully communicated to learners; rather, students should be allowed to construct their knowledge from their experiences (Piaget 1952). Both Piaget and Vygotsky held a constructivist view of the learning process, in which learners are given the opportunity to make sense and meaning of new concepts. Vygotsky (1978) perspective on inquiry learning as a constructivist claimed that where students actively process and construct knowledge for themselves with assistance they arrive at their Zone of Proximal Development (ZPD). In creating knowledge, learners can reach their (ZPD) through social interaction. These three theorists viewed learning as a continuous process centered on experiences that lead learners acquire knowledge by repeatedly reflecting on their experiences. Thus, in addition to the historical view of inquiry-based learning, it is also important to situate the current inquiry-based science instruction compared to the past inquiry-based science pedagogy in the classroom. This section of the study offers a synthesis of the historical perspectives on inquiry-based education, various definitions of inquiry-based learning from several researchers, key features of inquiry, tools to assess inquiry, and a summary that includes the gap my study addressed.

Inquiry-based learning is not a new concept in science education. It has been part of the learning process for years. The history of inquiry-based learning in science education arose from science education reform (Haefner & Zembal-Saul, 2004; Newman et al., 2004). It started with the Committee of Ten (National Education Association, 1894), which sought to change secondary education curriculum by standardizing and aligning programs at all grade levels. The Committee of Ten pursued changes that would require schools to prepare students for life rather than college. Students' curiosity needed to be piqued for them to seek after scientific understanding. Curiosity has been at the core of inquiry learning. Pine et al. (2006) noted the naissance of inquiry-based learning with Galileo's experiments in the 17th century. Galileo's hands-on experimental investigations on rolling balls down the ramps in attempting to discover answers to questions concerning the natural world showed inquiry in action. By the early 1900's, John Dewey emphasized the need to focus on scientific thinking rather than concentrating on facts. Dewey (1910) asserted that learners need to experience science and be active participants in their learning. He argued that knowledge is a form of intellectual practice and a prevailing tendency of the student's mind (p.125). He contended that learners need to gain authentic laboratory experience through observation, investigation, and drawing conclusions. These skills are indicative of the inquiry approach. Dewey urged educators to help the student do science rather than know science and provide a supportive environment in which students would become engaged in constructing their own knowledge (Dewey, 1910). Joseph Schwab equally contributed to the history of the inquiry-based approach in learning. In the late 1950s through the 1960s, Schwab wrote several books that impelled changes in science curriculum (Schwab, 1958, 1962, 1966). Running somewhat parallel to Dewey's views, Schwab echoed the significance of inquiry-based instruction in the school environment. He encouraged inquiry-based practices because they promote scientific reasoning and the development of metacognitive skills. Schwab emphasized the need for students to perform inquiry-based activities because they learn by doing, which the writer heralded in his book, *The Teaching of Science as Enquiry* (Schwab, 1962). Schwab used the term *enquiry* as part of his book title; however, the research term *inquiry* was used in this study. He also asserted that the laboratory environment provides students with a location to tackle scientific questions to arrive at solutions and acquire a fundamental understanding of scientific concepts. The laboratory setting provides the venue to engage both the hands and mind in the learning process. Students who are actively involved in the learning process through generating questions and performing investigations have a better understanding of scientific concepts as opposed to learning content facts of science (Schwab, 1966). Schwab advocated the tenets of the inquiry-based pedagogical framework to provide students with opportunities to explore alternative viewpoints and offer explanations of scientific investigations. Dewey heralded incorporating students' experiences as part of the learning process. Both writers foresaw the inquiry-based approach as an authentic approach to learning science concepts.

However, it was not until after the launching of *Sputnik* in 1957 that inquiry-based education became part of school curricula. The results suggested that learners who are taught using the inquiry-based approach outperformed others; however, exigencies for resources, and the limit on teachers' time hindered inquiry education considerably in schools through the 1980s. However, the National Science Education Standards with the support of the National Academy of Science fashioned the tenets of inquiry-based learning in 1996 (Pine et al., 2006). The launching of *Sputnik I* in 1957 inspired school leaders in the United States to question the condition of the science education from science teachers, science curriculum, and the methods of science instruction used in the school system. The launching of *Sputnik* propelled leaders to investigate the inquiry-based approach and examine its effectiveness in science education, sparking novel changes in science education observed in the American school system (Chiappetta, 2008; Collette & Chiappetta, 1994). Science teaching in the United States has progressed over the last two centuries from the delivery of scientific information as a body of knowledge to a method that permits learners to own and actively participate in the learning process through inquiry. Learning science through the inquiry process allows students to construct knowledge and challenge them to a deeper understanding of scientific phenomena through active investigation (Educational Broadcasting Corporation, 2004). The inquiry-based learning approach not only offers learners opportunities to generate authentic questions when their curiosity is piqued but also permit students to interact with conceptual scientific ideas to continuously fund their knowledge about the natural world in which they reside.

Over the course of historical research on inquiry-based learning, the definition of the term has changed. However, many researchers' definitions of inquiry-based learning have overlapped in meaning. According to Crawford (2014), the definition of inquiry-based science education (IBSE) varies. Inquiry learning approach is also referred to as project-based, authentic science, citizen science, and model-based inquiry. Quigley et al. (2011) defined inquiry-based learning as an instructional approach that offers students opportunities to actively engage in the learning process. Savery (2015) offered a similar definition but also added that inquiry-based learning is a student-centered. Learners are actively partaking in the learning approach through questioning, critical thinking, and problem solving. These definitions are superseded by the standardized meaning proposed by the National Science Education Standards (NSES) from A Framework for K12

Science Education (NRC, 1996/2012) and the Next Generation Science Standards (NRC, 2013). Pertaining to inquiry, the NRC 1996/2012 affirmed,

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

Inquiry takes on many meanings; but at its nucleus, the inquiry approach involves students actively constructing knowledge rather than absorbing facts. They participate in doing science as opposed to knowing it. Also, inquiry-based learning offers students authentic tasks intended to explore, master and expand on their existing knowledge to deepen their comprehension of the world around them. Notwithstanding researchers' definition of the term *inquiry*, students benefit when they own the learning process through active participation.

Elements of Inquiry-Based Learning

Authentic inquiry-based learning has several core features or elements. According to NRC (2012), these features are the crux of inquiry. First, during inquiry-based learning, students are engaged in scientifically oriented questions, an event, or a phenomenon. During this phase, students connect the new concepts to prior knowledge, which at times create conflict with their ideas but could also motivate them toward the pursuance to know more. Second, students learn to use evidence to support their claims or respond to their questions. They also learn to explore their ideas through hands-on practices, develop hypotheses, and construct explanations. Third, students make connections. They learn to analyze data and synthesize their ideas to clarify scientific knowledge and how the concepts could apply to new situations. The fourth and last feature is communicating the results and evaluation. Learners communicate and justify their explanations. During the last phase, students communicate their findings and assess what they learned and how they have learned the new concept. Bell et al. (2005) noted that at the center of the inquiry-based learning is students actively partaking in the learning process by answering research questions through examining data (p. 30). During inquiry-based learning, students learn to make observations, make inferences, develop hypotheses, design scientific investigations, and derive conclusions; these skills allow students to be critical thinkers and problem solvers (Quigley et al., 2011). Using these strategies, students can formulate new meaning and develop their communication proficiencies. These skills are systematized into the phases that shape the inquiry cycle, like the approach used to solve problems (Pedaste et al., 2015). However, Bell et al. asserted that any activity that does not involve students developing research questions and performing data analysis would not constitute inquiry. NRC 2012 affirmed that performing hands-on activities without these key elements do not guarantee inquiry learning is occurring. Bell et al. also acknowledged that authentic inquiry requires learners to answer their own questions through independent data analysis. Nevertheless, educators could still provide students with questions and data during the inquiry-based instruction with the understanding that the learners are ultimately responsible for analyzing the data to derive conclusions. These key elements are essential to authentic inquiry learning.

To assist students in developing these key elements of inquiry-based learning in order to become independent learners, teachers could scaffold for those who need assistance. These scaffolding strategies could assist learners through the learning process from (a) asking questions, (b) planning and execute investigations, (c) using equipment and tools to gather, analyze, and interpret data, (d) using data and evidence to substantiate claims, explanations, and models, and (e) communicating the steps of an investigation as well as the results and their explanation (NRC, 2012). Bell et al. (2005) remarked that scaffolding strategies are needed to help students progress to advanced inquiry skills. Savery (2015) agreed that inquiry instruction starts with the learner questions. Based on those questions, teachers encourage students to hypothesize and investigate solutions, construct new knowledge as they collect and understand data. Also, teachers facilitate learning in helping students to communicate their discoveries and learned experiences, as well as reflecting on their new findings.

According to NRC (1996), these key components of inquiry learning permit students to do science like real scientists. During inquiry learning, students are engaged in activities that develop their knowledge and understanding of the natural world. Based on the reviewed research, inquiry could be conducted in several ways, but key elements of the process should be included, and scaffolding strategies could be used to support learners in arriving at the advanced level. The inquiry process is cyclical and usually starts when students' curiosity is piqued towards additional knowledge acquisition. Their curiosity is followed by an investigative process to study the natural world. Then students could propose explanations based on the evidence derived from their investigation, and ultimately share their findings to expand science learning. All inquiry-based tasks must contain these mentioned features.

Tools for Measuring Inquiry-Learning

Aside from understanding what inquiry-based learning is, researchers have also worked to develop tools that help in observing and/or measuring various levels of inquiry-learning in the classroom. Using a four-level rubric to evaluate the occurrence of inquiry learning, Bell et al., acknowledged that students need the training to move through the first two levels confirmatory and structure inquiry; however, little to no assistance is given during the last two levels guided inquiry and open inquiry. Level 1 and 2 are referred to as cookbook labs, where students follow instructions to complete the desired task. Level 3 requires students to design and select their procedural approach with no assistance. Finally, at Level 4, students oversee their experiment from developing the questions to evaluating results to established conclusions. To arrive at the open inquiry level, students need to acquire a strong scientific foundational knowledge of the inquiry learning process via scaffolding. This approach is supported by the constructivist view on active learning. Learners need guidance to reach their ZPD.

Regarding tools for measuring inquiry, Pedaste et al. (2015) conducted a comparative analysis of 32 articles and proposed a comprehensive inquiry learning framework composed of five inquiry phases: orientation, conceptualization, investigation, conclusion, and discussion. The inquiry cycle is derived from the mentioned phases. The conceptualization is further divided into questioning and hypothesis generation while the investigation phase comprised of exploration or experimentation that leads to data interpretation. Additionally, the discussion phase includes reflection and communication (Pedaste et al., 2015). Similarly, De Jong and Lazonder (2014) also proposed a five-stage measuring tool to assess inquiry learning. Their version overlapped with Pedaste et al. (2015). Banchi and Bell (2008) offered a four-level rubric to assess the level inquiry, while Pedaste et al. (2015) proposed the five phases of inquiry. Both articles provided similar definition to the inquiry-based learning process as an active learning approach that requires students to critical think to derive conclusions. Furthermore, Bybee et al., (2006) proposed an inquiry-based framework of science teaching entitled the 5E learning model. The model is composed of five phases, namely engagement, exploration, explanation, elaboration, and evaluation. Several versions of the inquiry-based learning cycle appeared in the science curricula with phases ranging in number from 4E to 5E to 7E. The 7E cyclical model was created by Karplus in the late 1950s and fully developed by Atkin and Karplus (1962). It is consisted of elicit, engage: explore, explain, elaborate, evaluate and extend. Some these phases could be merged into a singular stage. One of the differences between E7 and E5 models is that engaging stage is divided into two separate categories, which are called *elicit* and *engaging*. However, the Electronic Quality of Inquiry Protocol (EQUIP) model is composed of 4 stages. The model was developed to gauge the extent teachers implement inquiry in their lessons using those four levels; they are preinquiry, developing inquiry, proficient inquiry and exemplary inquiry (Marshall et al., 2009). Regardless of the number of phases within the inquiry cycle, every cycle center on the same purpose (Settlage, 2000). Ultimately, these phases afford students with the opportunity to make observations, record data, formulate hypotheses, and organize their findings (Shaheen & Kayani, 2015). Several versions of the inquiry cycle have emerged from the literature review: some of them overlapped, while others differed in the naming of the phases or had the same phases broken into sub-phases. Overall, the various elements of inquiry learning are measured to assure that students receive the opportunity to emulate scientist by doing science.

The literature on the history of Inquiry-based Science Pedagogy began with John Dewey's experiential learning and Piaget and Vygotsky's constructivist perspective on inquiry-based learning, followed by several researchers defining inquiry-based learning including features and tools to measure inquiry learning. Although researchers have used several terms throughout the years to define inquiry-based learning, from experiential learning (Dewey, 1938/1997), active learning (Quigley et al., 2011), and student-centered (Savery, 2015), however, for this study, the established definition of inquiry set forth by NRC was used. This definition was used to guide in measuring the quantity and quality of inquiry facilitated in the classroom. Also, several researchers presented tools to evaluate inquiry learning. Banchi and Bell (2008) offered these four phases of inquiry: (a) confirmation inquiry (b) structured inquiry (c) guided and (d) open inquiry. De Jong also proposed five levels of inquiry entitled orientation, conceptualization, investigation, conclusion, and discussion, which Pedaste et al. (2015) used in the analysis of inquiry-based learning. However, this study used the EQUIP model to assess the level of inquiry of the biology simulations. Adopting the NSES definition and the EQUIP model for this study is significant in expanding the current research on education field on inquiry-based learning using simulations. Also, insights from this study may provide science educators with supplemental approaches for implementing simulations that not only help students understand biological concepts, but also provide students practice in scientific inquiry skills.

English Language Learners

The school system in America is as diverse as the county. The diversity is only increasing. With the rise in population of English language learners (ELLs), the academic achievement gaps between them and their native English language speaking peers still exist—from their primary grades through secondary, and even at the college level. ELLs are those students who are yet to acquire the English language and communicate their learning fluently and more efficiently: they usually need modified instruction to achieve success in academic and language courses (Abbott, 2014). They are recognized as the fastest growing group of students in the United States (Fayon et al., 2010). The number of ELLs in the school system in the United States has augmented by 51%. It is estimated that by the year 2050, ELLs will make up roughly 40% of the student population (Ardasheva et al., 2015). Other studies suggested the population will continue to rise (Ardasheva, Tretter, & Kinny, 2012; Fayon, et al., 2010). Given the increase of ELLs in the classrooms in United States, equity in learning is a necessity.

While the levels of English proficiency vary within the ELLs population, many still struggle with the English language. Several studies suggested giving students time (Cummins, 2001; Allen & Park, 2011), and others suggest incorporating language support during instruction (Echevarria, Vogt, & Short, 2004; Echevarría, & Short, 2011; Short, Fidelman, & Louguit, 2012; Gawne et al., 2016) help ELLs success. Others recommended the integration of literacy in inquiry learning to help them grasping science concepts and develop their second language proficiency with minimal modifications (Stoddart et al., 2002; Zohar & Barzilai, 2013). To develop their second language proficiency through classroom discourse, ELLs need support and time, Cummins (2001) agreed with the significance of classroom discussion to understanding science content and inquiry-based pedagogy. However, having the ability to follow directives and partake in what he called basic interpersonal communication skills (BICS), which takes 1-3 years to develop, is no indication that ELL students are ready for the cognitive academic language proficiency (CALP). Such proficiency takes 5–7 years to fully attain in a science classroom (Cummins, 2001; Allen & Park, 2011). Students are not yet able to understand explanations, idioms, and theoretical propositions in the second language (Gawne et al., 2016). Academic language is crucial to the academic success of English learners in science (Garza et al., 2018). ELL students' language proficiency improves with time, instructional modification, and language integration.

Though the number of ELLs in the United States has increased dramatically, the disparity in achievement scores persists (Callahan & Shifrer, 2016). ELLs still face various obstacles concerning academic language acquisition and other content areas, including biology. Some research on inquiry-based learning with ELLs has yielded positive results when language is integrated (Ardasheva et al., 2015; Buxton & Lee, 2014; Tong, Irby, Lara-Alecio, & Koch, 2014), and students also develop questioning skills (Taboada, Bianco, & Bowerman, 2012; Ulanoff et al., 2015; Wadham, 2013), and thinking skills (Zhang, Parker, Eberhardt, & Passalacqua 2011). Furthermore, ELLs perform better in inquiry-based assessments (Longo, 2011; Schiller & Melin, 2011; Songer & Gotwals, 2012; Songer & Ruiz-Primo, 2012). The results from these studies showed that ELLs benefit from inquiry-based learning. To that end, the aim of this study was based on the findings of these empirical studies to explore how biology teachers use simulations to promote inquiry with ELLs.

Characteristics of ELLs

ELL students struggle with academic language in many subject areas, including science. Per the National Center for Education Statistics (2014) ELL students have the lowest achievement scores in science. Because they are not proficient in the English language, they struggle with various courses requiring high academic demands (Abbott, 2014). However, they bring experiences into the learning process that influence their understanding of the different concepts as well as how much modifications they need (Fránquiz & Salinas, 2013). They are the fastest group of secondary school learners in the United States (Fayon et al., 2010). Wright (2010) noted that in 2000, of the 58 million children registered in pre-kindergarten through twelfth grade, about eleven million were immigrant students. Also, between the scholastic years 1997-1998 and 2008-2009, ELL students' enrollment rose to 51.01% (U.S. Department of Education, 2011). Several studies have suggested that secondary ELLs are envisaged to continue to rise (Ardasheva et al., 2012; Fayon et al., 2010). Not only are ELLs the fastest growing population in the US, but they are also incredibly diverse as a group and represent several languages, ethnicities, cultures, and socioeconomic strata (SES) (Abbott, 2014). Because these students are extremely diverse, science curriculum needs to also reflect this diversity to support their academic needs. Barrera (2016) conceded that students who are considered minority require extra educational attention, but often they do not obtain it, especially students who do not speak English as their first language. According to Tate (2001), educational equality is a civil right. Teachers are endowed with the responsibility to ascertain that they meet the educational needs of all the students in their care (Cochran-Smith et al., 2009). As the fastest growing population in the United States, ELL students' academic success in acquiring the language and the content areas is essential in attending college, choosing careers, and becoming productive citizens of the global community (Llosa et al., 2016). Research showed that ELLs are lagging because their needs are not met (NCES, 2012). With the rapid growth of the ELLs in the United States schools, it is imperative that content area classrooms reflect the culturally responsive curriculum to meet their language and academic needs. Aside from teaching content-area concepts, like science, educators can assist ELLs with reading and language skills.

ELLs in Science and Inquiry Learning

Researchers and teachers consider inquiry-based learning as an approach to arouse learners' curiosity toward the development of interest questions, application of research skills, construction of meaning, and gaining of scientific knowledge. Most ELLs require adapted instruction to partake in this approach to acquire comprehension of scientific concepts. However, the ultimate goals of science education are to equip learners with knowledge of the world around them so that they can become scientifically literate and acquire skills to pursue science-related careers. Effective strategies are needed to support their learning. Some empirical studies directly explore ELLs in inquiry learning environments; however, more studies are investigating ELLs thinking and science skills related to critical components applied during in inquiry learning. In this section, I discuss ELLs concerning, inquiry, English and science literacy, questioning and thinking skills, hands-on learning, and peer collaboration.

ELLs and inquiry. There are several challenges to implementing inquiry, particularly with ELLs; but studies provide pedagogy suggestions that benefit all students. Inquiry learning demands high-order thinking capabilities in which students ask scientific questions, design procedures, connect explanations to scientific knowledge, communicate, and justify the answers (Quigley et al., 2011; Zion & Mendelovici, 2012). Specifically, Quigley et al. (2011) acknowledged the importance of discourse and offered strategies to encourage dialogue rather than suppress it. Preferably using the teacher initiation-student response-teacher evaluation (IRE) model, which contains authentic discussion, Quigley et al. suggested teachers provide feedback in lieu evaluation. This teacher initiation-student response-feedback (IRF) model encourages students to dialogue and inquire more. ELLs benefit from inquiry because they ask questions, collaborate with others to investigate their hypotheses, learn to communicate their findings, and substantiate their explanations. Bunterm et al., (2014) agreed that inquiry is a process that mimics the methods that real-world scientists employ in scientific researches. Bergman (2011) further explained that ELLs learn by doing and peer interaction, during which time they can connect their learning in various situations. ELLs could benefit more when teachers provide follow-up information to extend ELL students' thinking and allow them to make connections to prior knowledge and other cultural experiences.

ELLs benefit from inquiry-based learning, with the integration of language in the science instruction. ELLs cannot learn science without language; language is fundamental to the scientific application and advancement (Ardasheva et al., 2015; Buxton & Lee, 2014, Norris & Phillips, 2003). The researchers acknowledged that teaching science to ELLs is a balancing act: teachers focus on content and language support. On the one hand, teachers structure their content-related instruction while on the other hand, they monitor their students' literacy learning processes. To achieve, ELLs need comprehensive input, in which they can grasp the essence of instruction to arrive at a high-level academic language to succeed in science. Buxton and Lee reviewed ELL science education in the United States and found when language teaching centers on the BICS instead of the CALP needed for academic learning. ELLs are positioned not to succeed. Also, ELL students' opportunities to partake in inquiry and learn science decline. However, the authors asserted that when afforded assessment opportunities equitable to learning, ELLs demonstrated high levels of science achievement and took ownership of their learning. Buxton and Lee highlighted the significance of language integration in the science curriculum to support ELLs. Ardasheva et al. (2015) completed a similar study on ELL science education inside and outside of the United States. Both articles provided a synthesis of quantitative and qualitative studies on science education for ELLs. The results are conclusive. ELLs benefit from collaborative learning and from accommodations customized to their linguistic and cognitive needs. Furthermore, Ardasheva et al. (2015) suggested a convergence of science and language for ELLs from three themes that emerged from their research using the theoretical framework Argument-Based Inquiry (ABI). They advised educators to take note of negotiation, embeddedness, and non-threatening learning environment to allow learning to develop with ELLs. In negotiation, students attain understanding through argumentation. Embeddedness involves the integration of language and literacy as integral parts of science, not independent of scientific learning. A non-threatening learning environment allows equitable access to learning for all. Research confirmed that when language is integrated into the science curriculum, ELLs benefit by acquiring both the content and linguistic skills.

In subsequent studies, Adams, Jessup, Criswell, Weaver-High, and Rushton (2015) utilized a written assessment to evaluate the effect of a guided inquiry lesson geared towards ELLs in a small, co-taught, high-needs secondary locale to support their linguistic and conceptual growth. Students worked collaboratively based on language and content ability with an emphasis on student-student discourse and hands-on investigation. The study yielded positive results based on the assessment. They also observed the phenomenon of code-switching, in which ELLs spoke in their native tongue at a high cognitive level. Similarly, Swanson et al. (2014) conducted a qualitative case study at Orchard, an urban high school in southern California. Approximately 33% of the school's students who were designated as ELLs participated in the discourse-intensive science and engineering practices. The study's findings revealed that educators employed three types of instructional supports to promote ELL students' argument from evidence and communicate knowledge. They utilized the learners' primary language support, deliberate scaffolds, and small-group instruction. The authors asserted that science content learned in the students' native tongue helped them acquire language content. ELLs can translate skills learned to make connections between the two languages. Visuals support with wording in the languages fosters language acquisition. Adams et al. (2015) recommended that educators encourage students to use their native language to help alleviate task that becomes more intense to support their learning in English. A balance of structured lessons that incorporate both languages seems to be the best approach for ELLs to learn science content.

Another way ELLs and inquiry learning has been studied is by exploring the language teachers use while facilitating inquiry learning. Researchers on inquiry-based learning have confirmed the link between inquiry-based instruction and effective communication. They suggested that more emphasis is needed on academic and everyday conversational language as the groundwork for discourse (Silva et al., 2013). Aydin (2016) investigated whether implementing inquiry-based laboratory experiments in science lessons enhances the communication skills of potential teachers using the mixed method approach with a sample of 78 prospective teachers. Data showed that communication skills improved when inquiry-based pedagogy is coupled with collaboration. Correspondingly, Hiltunen et al. (2016) collected data from 14 videotaped and audio-taped biology lessons incorporating some or all stages of inquiry-based pedagogy. They found that dialogic talk, which is when teacher replies to students´ views and responses rather than presenting their perspectives to the students, is more useful in inquiry-based learning than authoritative talk; however, they noted that teachers need more training on dialogic talk.

Undoubtedly, teachers play a significant role in instruction. Educators' talk directs the interaction between the students during the inquiry process and learning to scaffold and offering comprehensible input (Echevarria, Richards-Tutor, Canges, & Francis, 2011) to help ELLs move beyond the conversational English towards the more demanding and academic English that is required in science classes (Allen & Park, 2011). Educators can effectively communicate scientific concepts through dialogic talk with ELL students during inquiry learning to help them achieve what Dewey coined experiential learning.

ELLs English literacy and science literacy. Inquiry-based learning could improve students' scientific literacy. Using Inquiry-based learning can assist in achieving a synergistic relationship between inquiry science and language acquisition with ELLs. Integration of inquiry-based learning supports language acquisition to improve ELLs comprehension of content areas' knowledge (Carrejo & Reinhartz, 2012; Lara-Alecio et al., 2018; Stoddart et al., 2002; Zohar & Barzilai, 2013). Research showed that it takes ELLs five or more years to become academically English proficient (Collier 1987; Cummins 1991, 2001; Dixon & Wu, 2014; Genishi & Brainard, 1995; Thomas & Collier, 2002). Since teachers in some studies believed that ELLs needed to be proficient in the English language before enrolling in content specific classes, content area concepts were taught in isolation (Greenleaf et al., 2011; Stoddart et al., 2002).

Researchers reported that the years of remedial English courses helped ELLs acquire basic social communication skills; however, they were left in the precarious position of learning the complex academic language required to thrive in comparison to native English learners (Stoddart et al., 2002). Nargund-Joshi and Bautista (2016) compared the inquiry-based framework of science teaching of the 5E learning model (Bybee et al., 2006) and the Sheltered Instruction Observation Protocol (SIOP) model (Echevarria et al., 2004; Echevarría, & Short, 2011; Short et al., 2012). The 5E model is composed of five phases, namely engagement, exploration, explanation, elaboration, and evaluation. It is a sequential instructional model used in inquiry science education to help teachers approach instruction in a meaningful way, one that enhanced student learning. It is learner-centered and encourages students' learning motivation and performances in science education (Bybee et al., 2006; Bybee, 2014). Similarly, the SIOP model consists of eight components: lesson preparation, building background, comprehensible input, strategies, interaction, practice/application, lesson delivery, review, and assessment. The SIOP model has proven effective in addressing ELL students' academic needs through teachers' planning and lesson delivery. The two models are utilized in several studies to determine the impact of the constructivist approach in learning.

Within the building background component of the SIOP, frontloading ELLs with vocabulary is suggested (Short et al., 2012). However, Silva et al. (2013) argued that reloading ELLs with critical terminologies has also proven effective. Silva et al. proposed using reloading language by situating the meaning of vocabulary words with the context of the lesson. The researchers also advised that teachers provide the background knowledge students needed to understand general scientific meaning within academic language. They offered a sample lesson using middle school students exploring the concept of density in science and mathematics. Their experience showed how linguistically dense science concepts could be and how teachers can help students unpack them. In a similar study, Carrejo and Reinhartz (2012) performed a mixed-methods study analyzing fifth-grade state science and reading tests to confirm the effectiveness the model in inquiry-based learning. Likewise, teachers in this study utilized the 5E model to instruct science and language literacy with specific strategies. One of the strategies was vocabulary loops, in which one student starts the loop by reading the word until the last term is read. Aside from using strategies to improve learners' lexicon to establish background knowledge within a lesson, it is also important at the secondary level, by which time students are expected to have these strategies in their repertoires to learn content specific information without these explicit reading strategies (Tong et al., 2014). Also, they are expected to improve literacy through content instruction (Stewart-Dore, 2013). While some research shows that reading from early grade level may not transfer into content area literacy because less emphasis is placed on reading instruction when students reach secondary grades (Johnson, Semmelroth, Allison, & Fritsch, 2013). However, integrating science inquiry with science has revealed that ELLs made gains in their language proficiency and their conceptual science understanding (Tong et al., 2014). The literacy skills should be equally explicit at the secondary level because as students advance in a discipline, these skills become more demanding.

Silva et al., (2013) shared the results of their collaboration in understanding the complexities of academic language within the science classroom. They offered strategies they have utilized to instruct academic language to ELLs within inquiry-based science lessons. Using visuals, Silva et al. demonstrated how to support meaning making with the fusion of language and academic science. The 5E model has been used with writing to build academic language understanding (Huerta & Spies, 2016). Educators have also utilized it to collaboratively plan, instruct, and reflect on lesson design, leading to modifications to incorporate language development strategies that concentrated on language structures (Gomez-Zwiep, Straits, Stone, Beltran, & Furtado, 2011). The hybridization of science and language with hands-on teaching is characteristic of inquiry-based science in building conceptual and linguistic understanding for ELLs (Carrejo & Reinhartz, 2012; Silva, Weinburgh, Smith, Malloy, & Marshall, 2012). Recent studies of effective language development methods for ELLs have yielded positive results using inquiry-based learning in math and science instruction (Weinburgh, Silva, Smith, Groulx, & Nettles, 2014; Capitelli, Hooper, Rankin, Austin, & Caven, 2016). These studies are also supported by Stoddart, Bravo, Solis, Mosqueda, and Rodriguez (2011) in their investigation of utilizing inquiry-based learning with effective science teaching for ELLs as an approach to support them in developing academic language and literacy skills. Also, this has been confirmed by Dixon and Wu (2014) on literacy development across two languages that are mediated through social, cultural, and political contexts. The body of research supports the fusion of inquiry-based learning with language and literacy integration to support ELLs science and language development.

In a yearlong ethnographic study performed by Guccione (2011), he explored the integration literacy practices in an inquiry environment with first-grade ELLs. Inquiry-based learning was investigated using the student-centered approach in which the teacher provided guidance through scaffolding. Students performed independent and group investigations based on their interests. Guccione selected three first-grade Spanish-speaking ELLs with non-English proficiency based on their language scores. Data were collected once a week through video and audio recordings and through interviews with both students and a teacher named Brian at the beginning, middle, and at the end of the year. The author observed eleven literacy practices that ELLs used to construct meaning and interact as a community within the classroom; however, only five were profoundly analyzed: viewing, "I learned," interactive components, schema, and connections. Literacy practices were incorporated as tools to help instruction and record meaning rather than as an evaluation measure. In inquiry learning, literacy practices help ELLs to construct meaning before engaging in independent inquiry. ELLs acquire strategies to support their understanding, not necessarily to show that they had learned a new skill. The results revealed several benefits to using literacy skills in inquiry-based learning.

Reading is associated and equally affects ELL students' performance in science. Several studies have affirmed the benefits of reading integration in science. In a quantitative study, Maerten, Rivera, Myers, Lee, and Penfield (2010) examined student and school predictors of science achievement. This study involved 23,854 fifth-grade students from 198 elementary schools in a large urban school district with a high concentration of linguistically and culturally diverse students. They confirmed that reading is vital to science learning. Tong et al. (2014) also reported similar findings with inquiry-based learning that integrated reading and writing with 5th grade disadvantaged ELLs. A Daily Oral and Written Language in Science (DOWLS) activity was given during daily English lesson. Then, the students were given prompts to think, discuss with others, and write their responses. Using this approach, ELLs outperformed their peers in English-reading fluency, science, and reading achievement (Tong et al., 2014). Similarly, Lara-Alecio et al. (2018), in their longitudinal field-based research found that ELL students' language acquisition and science concept understanding improved with the implementation of literacy and the 5E model. Additional research supports this idea of merging language, reading, and science to support ELLs learning.

The conceptual framework for the Next Generation Science Standards (NGSS) advocates for the integration of language, reading, and writing in the use of inquiry in science teaching and learning to support ELL students' scientific thinking and discourse. NGSS calls for equity in education, where ELLs can acquire holistic learning rather than focusing on science vocabulary in isolation (NGSS Lead States, 2013). A merger of core scientific ideas and language is required to help ELLs attain the 21st-century skills needed to compete in this global society. Miller, Baxter, and Messina (2014) agreed with supporting ELLs in fostering the scientific practice of argumentation, which is one of the eight scientific practices in the Next Generation Science Standards (NGSS). In their study, they sought to equip all students, including ELLs, with language and science content skills. The authors recognized that all students face similar challenges in science courses: they must collaborate to develop scientific understanding and utilize language comparable to scientific researchers. NGSS demands that language is an integral part of the science content. The new language is not taught in isolation but instead is merged with fundamental scientific ideas and concept (Lee Quinn, & Valdes, 2013; NGSS Lead States, 2013). Using the language goals combined with content objectives, Miller et al., (2014) developed unit goals to help second and third-grade learners with crafting and actively listening to arguments with evidence to support their claims argumentation. At first, learners either agree or disagree with scientific claims; however, they started with simple sentences but develop evidence-based arguments in collaboration with others. They asserted that NGSS grants students the opportunity to grapple with scientific ideas as a group, supporting each other toward the same language content target.

Although presently the importance of hands-on inquiry continues to be a critical component of science instruction for ELLs, Burton and Lee (2014) conceded that hands-on activities do not automatically lead to conceptual comprehension. Bunterm et al. (2014) also acknowledged that hands-on activities that are not based on discovering answers to specific research questions are not inquiry. However, inquiry-based learning demands the purposeful integration of science literacy instructional models fostering both creative, stimulating science inquiry exercises and academic language and literacy skills.

Overall, these studies showed that ELLs could benefit from science literacy intervention when language and reading intervention are incorporated. Also, knowing how significant language is to learning any subject, and that ELLs seek to understand the phenomena occurring in the world around them, educators could empower them with reading skills and the language of science to partake in discourse that leads to logical conclusions. If ELLs can effectively learn, communicate, and grasp scientific texts, then their aptitude to excel in science would be more plausible.

ELLs and questioning and thinking skills. To demonstrate the effectiveness of inquiry learning and critical thinking skills acquisition with ELLs, teachers could incorporate the 5E model and the SIOP within their lessons. Nargund-Joshi and Bautista (2016) used both the 5E model and the SIOP framework to make learning meaningful through hands-on experiential learning and help students develop their cognitive skills. They combined the two models in a three-session lesson on land pollution. They used the 5E to help students build prior knowledge and then proceeded to instruct novel concepts through engagement in exploration and investigation. They also utilized the SIOP to support the introduction of key terms and unequivocally taught the content and language targets. Taboada et al. (2012), who also examined the impact of student questioning in ELLs, agreed that students' questions should drive reading comprehension by stemming from the critical part of the text. Ulanoff et al. (2015) explored the questioning skills of Spanish-speaking ELLs in kindergarten and third-grade. Similarly, Howes, Lim, and Campos (2009) demonstrated that inquiry-based learning stimulates curiosity, which produces questions. Regarding questioning skills, Harvey and Goudvis (2000) claimed that the questioning strategy is what drives learners toward their understanding of texts. They therefore encourage teachers to design classrooms that incite passionate curiosity. Harvey and Goudvis confirmed that curiosity drives students to generate questions; the questions are vital to understanding and help explain any confusion. Furthermore, questions encourage further research and push learners to seek answers and achieve a deeper understanding of the world around them.

Nargund-Joshi and Bautista (2016) connected the engage stage of the 5E model, in which educators elicit prior knowledge during the building background phase of the SIOP to introduce scientific concepts. During session one, the engage/building experience, students used T-charts to develop key terms from observing pollution from the classroom garbage can and assigned pictures. Students worked in small groups to discuss their thoughts, recording their responses in their science journals. These skills enhance ELLs proficiency in thinking, collaboration, and language proficiency. The second session focused on exploration, which correlated to the comprehensive input, strategies, interaction, and practice. Again, students collaborated in groups of two to classify and categorize various objects that either increase or decrease land pollution at six stations. Students were also informally assessed by answering questions on their reasoning behind their categorization of specific objects. In the last session, which entails elaboration and evaluates, practice/application, and review/assessment, students continued to work in groups to investigate types of waste at the school and develop a plan to help the school reduce its pollution. The groups had to interview staff on waste management, focusing on the school's current recycling practices. They also reviewed existing community programs that would benefit their school. Using collected data, students created and presented their results before justifying their recommendations based on their findings. Nargund-Joshi and Bautista (2016) showed that linking the two instructional models could enhance ELLs scientific understanding and empower them to become problem solvers and critical thinkers. Language learners collaborated with native speakers and used scientific thinking throughout the pollution lesson. They demonstrated their learning by designing and presenting on recycling plans for their school. The authors asserted with planning. The SIOP, as an assistive language framework, could be combined with all phases of the 5E model to provide ELL students the opportunity to learn science content. Thus, this study confirms the significance of using two different instructional models to aide ELLs in gaining science content and improving their inquiry skills by integrating language, negating the belief of teaching ELLs language in isolation.

Moreover, ELLs acquire critical thinking and questioning skills during inquiry-based learning. In a qualitative, narrative study, Ulanoff et al. (2015) explored the development of academic language and discourse using questioning skills in six kindergartens and six third grade ELLs in the context of inquiry-based learning in Spanish. In this study, ELLs focused in developing questioning skills within four lessons centered on the Activity that Integrate Math and Science (AIMS) model as a means of promoting thinking skills. Third-grade students played the teacher's role in inquiry-based activities that developed and facilitated their questioning skills with kindergarten learners. Inquiry-based learning was utilized as a pedagogical teaching approach with the project or problem-based to support acquisition of critical thinking skills (Zhang et al., 2011). It also supports language ability to partake in discourse (August et al., 2014; Hakuta, Santos, & Fang 2013) and questioning skills (Wadham, 2013; Taboada et al., 2012). The experts, third-grade students, partook in 45-minute lessons; then they taught the same lessons to the kindergarten learners for 45 minutes. One of the researchers also guided the lessons. The results showed that in the first three lessons, the third graders helped the kindergarteners answer the inquiry questions and used the same questions their instructor had used. However, by the fourth lesson, students asked original questions within the familiar questioning context of literacy. Ulanoff et al. (2015) asserted that using expository text combined with science or math could help learners develop questioning skills in content areas. The study lasted six weeks, with students receiving about 90 minutes of instruction. The researcher also taught the classes, provided field notes, recorded reflections, and provided first-person narrative with excerpts of shared experiences. Also, the researcher provided numerous sources to record and analyzed the data during a short period. This study is significant as it contributes to the body of research on ELLs to acquire higher order thinking skills through inquiry-based learning using questioning skills in social constructs.

In another study, Howes, Lim, and Campos (2009) showed that when inquiry-based learning is utilized, it complements the natural curiosity of the learners by urging them to pose questions, apply their knowledge, and develop conclusions. They are offered more hands-on activities with the intention of making science more active and physical and permitting learners to feel capable with the subject through this approach. Their research involved three elementary teachers who collaboratively endeavored to teach literacy through science. However, the educators taught for inquiry, a process in which learners practiced and developed the skills needed to perform inquiry. They asserted that in contemplating teaching for inquiry, teachers can maintain the authenticity of literacy integration to spur on learners' questions about their surroundings. The practices of encouraging students' questions and supporting them to employ evidence from the real world to investigate these questions are both critical to inquiry-based pedagogy (Howes et al., 2009). One of the primary goals of scientific inquiry is to involve students in the activities and thinking processes of scientists to foster a conceptual understanding of the natural world. During inquiry learning, learners go beyond following experimental procedures to verify science concepts. They are thoroughly involved in the process of investigation through constructing knowledge, interpreting information, supporting claims, and collaborating with others. Therefore, ELLs not only acquire the language, questioning, and thinking skills, but they also foster the understanding of scientific concepts.

Based on the supposition that questioning can drive comprehension, Taboada et al. (2012) confirmed the benefits of questioning for learners. They examined the effect of student created questions to expository texts among ELL and non-ELL students in 5th grade. They asserted that high cognitive questioning promotes comprehension. Using the Woodcock-Munoz Language Survey Revised-Battery, students completed a vocabulary assessment. Then they had to develop their questions from a given science text and completed a multiple-choice and open-ended questions assessment. The assessments were scored in a four-point rubric, and the results showed non-ELL perform better on student-made items, while ELLs showed similar performance in vocabulary comprehension. ELLs benefit from the higher cognitive questioning. The studies revealed that questioning and thinking skills could be supported by piquing ELL students' interest towards using inquiry skills to assess their understanding, derive alternate responses, and apply their knowledge in novel situations.

ELLs and assessment. Another way that ELLs and inquiry learning have been studied is by looking at how these students perform assessments. Assessment of learning plays a central role in formal education (Fensham & Cumming, 2013). Per the National Research Council (NRC; 2001, 2012), assessment in science education has three main targets: formative assessment, summative assessment, and assessment for program evaluation. In 2015, President Obama signed Every Student Succeeds Act (ESSA), which replaced the No Child Left Behind Act (NCLB). The former allowed states to develop their accountability system to support schools and districts (Darling-Hammond et al. 2016). ESSA calls for equity in the education system, in which all learners receive meaningful learning opportunities. Funding and resources are provided to high-poverty areas. Also included as part of the test-based accountability is ELLs achieving language proficiency (Darling-Hammond et al. 2016). With the newly instituted accountability system, districts could develop fair testing measures to diagnose ELL students' skills and language acquisition. School districts could create assessments that would reflect these students' critical thinking and allow them to demonstrate integrated learning.

Obtaining lower scores on standardized tests affect ELL students' success. Multiple attempts on the standardized test have not motivated ELLs to perform better; rather, students develop the academic mindset to concede. Denzine and Brown (2015) have focused on the direct link of motivation to students' achievement. It is a critical component in the success of language learning and has an impact on the performance of

English language teaching (Jin, 2014). Recent research in high-stake testing showed that ELLs perform lower on content area exams, which impede their motivation (Rodriguez & Arellano, 2016). The educational gap also exists in science achievement between native English and non-native English students, and it is increasing at a rapid rate (Garza, Kennedy & Arreguin-Anderson, 2014). Rodriguez and Arellano (2016) showed that Latino students obtain lower average scores on subsequent attempts in the California High School Exit Exam (CAHSEE). In a similarly study, Turkan and Liu (2012) used a sample of 1,396 seventh- and eighth-grade students that took the science test. Their sample included 313 ELL students. The findings revealed that non-ELLs significantly outperformed ELLs.

Early intervention is vital in preventing the achievement gap between ELLs and their counterparts (Heinrich and Leserman 2014; Lara-Alecio et al., 2012). To bridge the gap between ELLs and their peers, practical strategies that have been proven to be successful should be utilized. Teachers play a significant role in student learning, and their effectiveness is measured by their students' outcomes. Instructional practices could be modified to promote ELL students' language development. However, school districts are obliged to invest in educators' training and encourage teacher-to-teacher collaboration to equip them with the expertise needed to assist ELLs. Science teachers are conscious of essential and useful strategies and their implications for instructing ELLs. Astute teachers can incorporate cultural content into science to help ELLs attain content mastery and develop English competency to bridge the achievement gap and attain success.

However, inquiry-based assessments use different approaches than traditional standardized tests. Rather than employing all multiple-choice questions, science educators administer several formative and summative assessments that compel students to demonstrate their learning (Songer & Ruiz-Primo, 2012). Researchers acknowledged two types of assessments that teachers utilize in inquiry-based learning: summative and formative (Liu, Lee, & Linn 2010; Schiller & Melin, 2011). Summative assessments allow educators to assess students' current knowledge; however, they do not demonstrate the students' learning progression (Schiller & Melin, 2011). Both are important in inquiry-based learning. Summative assessments provide students with their current performance, and they can take control of learning. Similarly, formative assessments allow students to monitor their learning, in which educators detect misconceptions, and recognize their pupils' strengths and weaknesses. Knowing this information, teachers could then guide students towards the critical thinking process and deepen scientific discoveries. In their study, Schiller and Melin (2011) provided several formative assessment approaches. Students can demonstrate their learning by creating a show and tell the board and use think dots to share their knowledge. For example, Schiller and Melin (2011) evaluated the use of a literacy technique called RAFT, in which they assume a role, consider their audience, write in a format, and examine a topic from a relevant perspective. The RAFT assessment provides valuable feedback about students' learning within a unit lesson, and it encourages writing across the curriculum. Inquiry-based assessments are more authentic since they include labs and classroom discussion, scientific explanations, and argumentation (Songer & Gotwals, 2012). Longo (2011) examined inquiry-based science lab activities and attested that formative laboratory reports are efficacious in assessing inquiry as they allow students to think critically through problems, plan their experiments, and derive conclusions from the learning process. Conversely, in performing traditional laboratory experiments, students can enjoy executing the lab but not grasp the concepts and the real-world applications (Putti, 2011). During inquiry-based assessments, ELLs are given the opportunity to demonstrate their learning in various ways. They can articulate scientific concepts using their words, monitor their progress, receive feedback to adjust their learning, and advance towards content and linguistic progression.

Using inquiry-based assessments with ELLs has also revealed an increase in achievement. Take, for example, the Science Instruction for All study that examined the effect of science and literacy intervention to promote achievement with 374 third and fourth grade culturally diverse students for three years at six schools. The findings indicate achievement growth regardless of cultural and language (Ku, Bravo, & García, 2004; Stoddart, Solis, Tolbert, & Bravo, 2010). The evidence is also confirmed in the Valle Imperial four-year project with ELLs in grades K-6 (Amaral, Garrison, & Klentschy, 2002). Assessments were given to a total population consisting of 615 students in fourth grade and 635 students in sixth grade who participated for the duration of the project. Students' scores were increased with the number of years they attended (Ku et al., 2004; Stoddart et al., 2010). Results from both studies show that inquiry-based learning provides ELLs opportunities to cultivate scientific understanding, while simultaneously enhancing their language skills. Students achieved positive outcomes in both science content and language because hands-on activities are less dependent on language proficiency.

Multi-faceted assessments including inquiry-based learning not only offer ELLs a path towards language acquisition but also provide them with opportunities to gain scientific understand and achieve academic success. Faggella-Luby, Griffith, Silva, and Weinburgh (2016) qualitatively explored the use of alternative assessments to measure the impact of science instruction on ELL students' abilities to grasp an informational trade book text. They utilized a sample of 47 fifth-grade immigrant students to the United States from a large urban district in the southwest. The students had to restate an informational text on wind energy and wind turbines. Students received 14 days of hands-on instruction on science concepts and were assessed both on the level of reading comprehension and the level of science understanding. They took a pretest on day one and a posttest on day 14 showing their learning. The findings showed that ELLs who acquired the instruction demonstrated accuracy in retelling informational text at the reading comprehension level and deeper understanding of science concepts using coding analysis (Faggella-Luby et al., 2016). However, these results should not be generalized to all ELLs, since the researchers' sample was composed of ELLs whom the state considered to be advanced high in language proficiency. Their level of communication skills was varied; nonetheless, they knew enough of the English language to perform well.

In summary, inquiry-based science instruction provides ELLs the pathway to authentically communicate their understanding using various formats. Given these opportunities to learn science as scientists do, ELL students cultivate the English lexicon and language rules to write and speak well enough to learn the science content and increase their achievement scores. Noting the compelling nature of the evidence on inquiry-based science instruction in the literature and its impact on ELL students' language suggests that educators must focus on helping these students improve their scientific skills while simultaneously acquiring the language. Using scaffolding strategies and being culturally responsive, teachers could make the content comprehensible and assist with language development. ELLs, like English-speaking learners, need feedback. Notwithstanding their language barrier, their ability to partake in inquiry-based learning and acquire critical thinking, problem-solving, collaboration, and communication skills remain relevant and paramount.

ELLs and peer collaboration. Collaborative learning is essential to ELL students' acquiring content and language; more importantly, collaboration with their peers allows them to interact socially and arrive at obtaining necessary skills towards academic language. Several studies support collaborations among teachers to assist ELLs in meeting standards (Koelsch, Chu, & Rodriguez Bañuelos, 2014), to equip teachers to work with ELLs (Jimenez-Silva, Rillero, Merritt, & Kelley, 2016), and mentor and train new ELLs' educators (Hansen-Thomas & Grosso Richins, 2015). Correspondingly, numerous studies confirmed the benefits that peer collaboration has on ELLs to meet their instructional needs (Russell, 2012; Baecher & Jewkes, 2014), respond to their communication and social needs (AbuSa'aleek, 2015; Hynes, 2014), develop thinking skills (Zhang & Dougherty Stahl, 2011; Zhang, Chunling, Munawar, and Anderson, 2016), their writing needs (Kim, 2015), and build vocabulary and literacy skills (Ganske & Jocius, 2013; Peercy, Martin-Beltran, & Daniel, 2013). All these studies substantiated the significance of collaboration to support ELLs and the benefits of peer collaboration in the learning process.

Recent professional development studies show success in supporting science teachers in their use of collaborative learning with ELLs. Koelsch et al. (2014) studied the collaboration with subject-area teachers of ELLs to develop their knowledge and instructional relevance to instruct ELLs into disciplinary practices and the language they require to partake in these practices. With the understanding that ELLs need language to engage with core concepts and interaction with each other, Koelsch et al. (2014) focused on two aspects of language that are aligned to Next Generation Science Standards (NGSS). The two aspects are language as action and language for learning. During professional development, teachers collaborated to create lessons around the two aspects involving the Extended Anticipatory Guide (EAG) and Novel Ideas Only (NIO). The EAG includes developing statements with the major concepts, and then allows students to communicate their opinions. The NIO entails collaboration among ELLs of different language proficiencies to listen, read, speak, and write on an idea. This training required a shift in how teachers approach discussions to emphasize both language as action and language for learning. Discussions focused on asking questions, seeking solutions, and strengthening teacher reasoning regarding how language can provide academic support for developing comprehension and increasing involvement in disciplinary practices. This approach is like the inquiry process or the problem-solving model where learners would grapple with questions or problems and collaborate to derive answers. Boothe and Caspary (2016) agreed that collaborative learning activities prepare ELL for 21st-century global workforce. ELLs benefit from science educators using collaborative learning not only to support their academic success but also to acquire skills to successfully compete in the marketplace.

Aside from helping ELLs to meet established instructional standards, teachers are faced with obstacles regarding best practices to ensure academic success and promote learning in working with ELLs. Data from existing literature indicate that teachers of ELLs tackle social, institutional and personal obstacles (Khong & Saito, 2014). Helfrich and Bean (2011) conducted a study which revealed that novice teachers do not perceive themselves as being sufficiently prepared to teach literacy skills to ELLs. ELLs require differentiated instruction to succeed academically. In a qualitative study, Jimenez-Silva et al. (2016) focused on some of the obstacles through faculty members collaborating to change the culture where all members support prospective educators to work with ELLs. Through peer-mentoring, novices and veterans can engage in mutually supportive relationships to assist ELLs in meeting their academic needs. Valdiviezo (2014) asserted that teachers must be trained on how to address student diversity through multicultural examples to support their ELLs. Jimenez-Silva et al. (2016) study had three of the authors as participants. They aimed to have student teachers implement problem-based learning (PBL) with ELLs in their student teaching experience with the support of their mentor teachers and university supervisors. Hansen-Thomas and Grosso Richins (2015) found that peer mentoring can be an effective component of professional development for

ELLs content teachers. Jiminez-Silva et al. (2015) also noticed encouraging results from their professional development integrating PBL and strategies for supporting ELLs. These studies are significant in demonstrating that teachers' collaboration allows educators to focus on supporting their learners' content and language needs. Through collaboration and mentoring relationship, teachers gain insights to surmount obstacles and acquire strategies to assist ELLs in their classrooms.

Collaboration could improve ELL students' vocabulary and social skills. Knowing the importance of vocabulary and the value of giving students opportunities to engage with words and develop language skills, Ganske and Jocius (2013) studied how developing ELL students' vocabulary to participate in interrogation via small group interactions influenced their thinking during teacher and student talk in small-group word study instruction. Ganske and Jocius (2013) conducted a qualitative study in an urban school district in the Southeastern United States in third- and fourth-grade classrooms. Within four schools in the district, the students' population demographics ranged as the following: Black 19% to 42%, Hispanic 19% to 48%, White 28% to 59%; free and reduced lunch 63% to 90% (pp 28-29). A total of 40 students were selected based on cultural and linguistic diversity, and two classrooms were observed on word study groups. Findings showed that teachers' talk dominated the classroom interactions, and these teachers asked low-level questions. Word study sessions were reduced to 15 minutes because teachers focused on standardized testing; therefore, students had minimal time to focus in discussions and debates to develop their academic language. The authors reported that of the 36 discussions, only one met the requirements of extended discourse by 7 minutes, 10 seconds. Word study allows students to learn how to examine words and understand their meanings through hands-on activity. Though Ganske and Jocius's study did not reveal favorable results of the effectiveness of word study and how ELLs could benefit from participating due to teacher's ineffective practices, the authors acknowledged that small-group word study instruction is effective but that enough time must be allowed for discussion and thinking. Moreover, word study must be sufficiently challenging and simultaneously engaging for learners to develop their thinking. Offering students active learning opportunities incites curiosity, which drives the quest to acquire knowledge and understanding. Furthermore, collaborative discussions are helpful in supporting social interaction.

In addition to improving vocabulary and social skills, collaboration supports reading and writing skills. ELLs learn better in active and collaborative environments that provide them with meaningful discussions into small group word studies to support their learning, and develop their writing skills (Kim, 2015). Peercy et al. (2013) explored collaboration among teachers and families to support ELL literacy via after-school programs. Participants in their qualitative study included 40% ELLs and family who participated in literacy night activities. The findings confirmed the positive impact of collaboration in supporting ELLs literacy when children and parents spent time reading together at home. Also, Kim (2015) provided evidence of collaborative learning in developing ELL students' vocabulary and writing skills. The author contended that writing as a process that can support ELL students' language proficiency. Writing is a dynamic and iterative process. The author suggested using peer review within the writer workshop activities, which entails collaboration among learners. Students receive and provide feedback to improve their writing skills. Kim (2015) provided three steps in implementing peer review with ELLs and acknowledged their language needs. Teachers must include feedback before, during, and after training to support ELLs with their writing skills, not neglecting that they have varied language proficiency and lack of confidence in giving and receiving feedback. Writing is difficult within itself; ELLs need more time, instruction, feedback, and practice to improve their writing skills (Kim, 2015). Altogether, ELL students' reading and writing skills improve when they partake in collaborative learning and are afforded time with modification to become proficient.

Several studies revealed the significance of peer collaboration in fostering communication, thinking skills and academic success in ELLs. Educational needs of ELLs in mainstream subject area classrooms are different when compared to the needs of native English learners (Russell, 2012; Baecher & Jewkes, 2014); hence, modifications are needed to support their instructional needs. In two separate studies, Zhang and Dougherty Stahl (2011) and Zhang et al. (2016), collaboration reasoning (CR) was used to promote collaborative discussions in Spanish-speaking ELLs. During CR, learners work collaborative in small groups. Learners do not have to raise their hands to participate, and the session is peer-led. This discussion method aims to support intellectual and personal engagement among learners. Zhang and Dougherty Stahl (2011) affirmed the research from the past two decades that provide evidence that CR has positive impact students' thinking, learning, and social skills. CR is beneficial to ELLs because it allows students to interact and collaborate with each other with infrequent teachers' interventions. In a mixed-method study, Zhang et al. (2016) examined two mainstream classrooms of 27 fifth graders with 14 students in a bilingual class, and 13 who participated in eight peer-led literature discussion using CR. The researchers measured discussion proficiency using Pearson correlation and independent sample *t* tests of oral English skills, such as sentence grammar, and reading comprehension. They also measured the students' English language use at home and parental assistance with homework, the researchers' results showed discussion proficiency varied between the ELLs and mainstream students. These results are expected, since ELLs are in the process of acquiring the language and need more time, while mainstream students already mastered the English language. However, the study did highlight that ELLs gain several skills during collaborative learning. They think critically and evaluate information to participate in discussions. ELLs learned to construct their arguments and interact with their peers. In addition to improving language learning and developing reasoning skills, collaboration also supports ELL students' social needs. Both AbuSa'aleek (2015) and Hynes (2014) explored the use of social media, specifically Facebook (FB), in facilitating language learning and interactions among ELLs. While AbuSa'aleek investigated the use of Facebook as an ELL's learning environment which could improve students' learning of English and their perceptions towards learning English, Hynes focused on leveraging Facebook as a tool to instruct ELLs more than what the site demands of its users by integrating learning within the social interaction. AbuSa'aleek (2015) conducted a quantitative survey of 65 students regarding their perceptions towards learning English in the Facebook. The findings revealed that students gain confidence and motivation for

English language learning, confident that FB facilitates and encourages them in learning English. Hynes (2017) reviewed several qualitative and quantitative studies that suggest FB as a collaborative platform for learning. In another study, DePew (2011) noted that students used FB to connect with others from their culture. Communication within culture still advances ELL students' language skills, as culture does not necessarily mean intellectual or similar language proficiency. The studies affirmed that FB provides ELLs a platform to collaborate and communicate and that the platform has significant implications for the language and composition in the learning environment.

An overwhelming body of research supports collaboration. However, in a quantitative study, Liu and Wang (2015) examined the effectiveness of small group, pair work, and independent reading comprehension performance of ELL students in fourth grade. Using both linear regression and correlated analysis on results gathered from Progress in International Reading Literacy Study (PIRLS) and National Assessment of Educational Progress (NAEP), they concluded that small-group intervention and pair work were not useful for fourth grade level ELLs. Rather, independent reading in which students read books that piqued their interests improved ELLs reading proficiency. Group work is not synonymous with collaboration. Students could work in pair or small group to complete a task or activity without collaborating. Also, working in small group and in pairs does not necessarily imply that inquiry-based learning is occurring. Inquiry-based learning involves students investigating their queries to arrive at various solutions. Yet, this study is significant in explaining the ineffectiveness of small group reading with ELLs. The findings showed that ELLs need silent reading to develop comprehension, not small group interaction. Also, ELL students' reading scores increase when books of their choice are read. Reading aloud benefits ELLs as they hear the words in their own voices, and others can give them feedback on pronunciations of key terms; however, when reading in small groups, they do not get enough time to process and understanding what is read. Although Liu and Wang's study seems to contradict previous research on collaboration and its effectiveness with ELLs, using small group and pair work is not tantamount to collaboration and inquiry. Research confirmed that collaboration is beneficial to ELLs in improving their thinking skills to achieve academically and socially.

ELLs and Technology Learning

Technology allows ELLs to partake in collaborative learning. In addition to ELLs being impacted by collaborative learning, technology also impacts ELL students' learning experiences. Technology plays a significant role in learning; but more importantly, its integration improves the learning prospects for all learners, including ELLs. Fullan (2013) noted that the integration of technology, when coupled with the appropriate pedagogy, can open students and teachers to entirely new learning prospects. According to the U.S. National Educational Technology Plan, new technologies need to provide engaging and effective learning experiences. Also, new technologies must include content, resources, and assessments that measure student achievement in a more complete, authentic, and meaningful ways (U.S. Department of Education, 2010). Although it has been proven that supporting inquiry-based learning with technology is effective (Ucar & Trundle, 2011), research showed that many students have difficulty gaining access to the available technologies because of the digital divide known as the regional inequality (Koyunlu, Dökme, & Sarıkaya, 2014). Also, Darling-Hammond, Zielezinski, and Goldman (2014) brought to the forefront the disparity that exists in technological access, ownership, and internet access across socioeconomic groups. Darling-Hammond et al. (2014) acknowledged that more than half of the public K-12 schools do not have the broadband to sustain all their students being online at once. Technology integration in education is changing how students learn, but it is not without challenges. Educators are expected to incorporate it to meet the need of ELLs and prepare them for the ever-changing technological world. The inequality of technological access needs to be addressed so that ELLs can acquire engaging and effective learning experiences.

One of the frameworks that have been used in several studies to assist educators with the integration of technology within their lessons is the Technological Pedagogical Content Knowledge (TPCK). Several studies focused on the Technological Pedagogical Content Knowledge used in assisting learners with the advancement of technological skills. Mishra and Koehler (2006) coined this framework; the letter "a" was added for better pronunciation of the acronym, so it could be read TPACK (Total PACKage) rather than TPCK. The framework is nucleated on understanding the knowledge required for teachers to effectively incorporate technology with their content-area pedagogy. Altogether, the researchers advocated the integration of three core knowledge domains among educators, technology, pedagogy and content knowledge. Combining these components within teaching is complex; therefore, the framework is developed to help researchers and educators understand and examine the specialized and multi-faceted forms of knowledge that are required for teachers to successfully incorporate technology in their teaching (Koehler, Mishra, Kereluik, Shin, & Graham, 2014; Mishra & Koehler, 2006). In addition to integration of technology and content knowledge, ELLs need comprehensible input to become linguistically and technological proficient. Sox and Rubinstein-Ávila (2009) proposed the adaptation and use of web-based interdisciplinary collaborative learning units to incorporate technological experiences at the secondary level to support the linguistic development of ELLs. They focused on WebQuests strategies such as highlighting key terms, detailed instructions, and chunking text to support ELL students' language barrier. Revision of eight WebQuests showed minimal evidence of linguistic support for ELLs. They offered a rubric to help educators focus on three areas of support for ELLs: language, multimedia, and organization. Sox and Rubinstein-Ávila advised selecting WebQuests with ELL students in mind, meaning those that use technology as a tool to address ELL students' instructional needs. Research revealed that if at-risk learners acquire ready access to suitable technology used in thoughtful ways, they can achieve considerably in learning and technological readiness (Darling-Hammond et al., 2014). Sox and Rubinstein-Ávila confirmed the use of simulations positive affecting test scores from the National Assessment of Education Progress (NAEP) data analysis in comparison to the drill and practice. Ucar and Trundle (2011) noted that the classroom can sometimes be insufficient in collecting data during the inquiry process. Technology can provide students with opportunities to move beyond the classroom and connect their learning to real-world situations. TPACK provides educators with the framework to assist ELLs with the necessary skills to compete in the digital world.

Integrating technology could help educators better understand ELLs and provide them with effective classroom instructional and technological skills they need to become successful. In a quantitative study using 220 ELL and non-ELL fifth-graders, Ryoo (2015) examined how in web-based learning, using all languages from a linguistically mixed classroom could support all leaners' science acquisition. Acknowledging that it takes ELLs longer to acquire academic language versus developing fluency in everyday language or conversational English, Ryoo (2015) developed interactive, web-based instruction on photosynthesis and respiration. This approach could mitigate the level of cognitive load ELLs need to grasp complex scientific concepts when they have not acquired the academic language to contend with their non-ELLs counterparts. Out of 220 students, 68 were classified as ELLs that spoke Spanish, Tagalog, Samoan. Students attended three days of 60-minute sessions consisting of computer or web-based instruction on photosynthesis and cellular respiration in everyday English, while other students complete the same concepts using the web-based textbook version. The web-based version was composed of multiple representations, including text, animations, and narration. Each activity had dynamic visualizations that allowed students to explore unseen, abstract processes of the concepts. Each activity also used both audio narration and informational texts. Students could play the narration several times by clicking a speaker icon to navigate the instruction at their own pace. Through this approach, students could comprehend the concepts at various English proficiency levels. Also, including the dynamic visualizations made the abstract concepts and scientific terms comprehensible. Students who participated in the everyday English received instruction on the concepts prior to introducing the scientific vocabulary, while the other group were taught the same concepts and key terms simultaneously in everyday English. Based on post assessments, multiple-choice, and essays, the analysis using ANOVA showed no statistical significance in understanding the concepts between the two groups from the multiple-choice assessment. However, with repeated ANOVA analysis of condition and time, the results indicated a significant effect between time and condition, which showed that ELLs benefited from web-based instruction over time.

Based on research, ELL students need more time for comprehension and academic language achievement. Kyoo (2015) also noted the difference in comprehension from the pre-test in which 70% ELLs selected "I don't know" as a choice, as compared to non-ELLs at 16%. In the everyday English group, students could link their conceptual understanding to content to scientific terms in the essay portion of the assessment. All learners improved their understanding of the concept, but non-ELLs showed significantly higher gains than students in the textbook version. Compared to ELLs, non-ELLs are equipped with more vocabulary terms, and are already proficient in the English language. Therefore, ELLs would have more difficulties using scientific terms to develop and elaborate on their ideas in the written form. Integrating technology with conversational language to support ELLs in learning science proved to be effective instructional approach towards narrowing the technological discrepancy and assisting ELLs with achieving academic language competency.

Closing the technological gap is significant, for the intent of this study was to explore how biology teachers use simulations to promote inquiry learning with ELLs, and technology integration is imperative in virtual simulations. Darling-Hammond et al. (2014) showed that simulations have a positive effect on test scores. Their research is substantiated with reviewed literature demonstrating that science simulations are positively correlated with academic performance (Rutten et al., 2012; Zhang, 2014;). Lee and Tsai (2013) analyzed thirty-six articles based on educational technology and biology dated from 2001-2010 using simulations or visualization tools. The results suggested that more studies should use technologies for interdisciplinary training and for supporting problem-solving skills. Problem-solving skills are imperative in active and inquiry-based learning. In their case study, using third and fourth grade Korean newcomers to the southwest United States, Hur and Suh (2012) investigated the effectiveness of active learning for ELLs exploiting technology in the classroom. The students were introduced to English in a 60-hour intensive language program using interactive whiteboard, podcast, and digital storytelling for language proficiency development. In their classroom, an interactive whiteboard was used for interaction and presentation. Teachers developed podcasts to provide ELLs with authentic, contextualized vocabulary terms, and language examples in application. Results revealed that digital storytelling assignments afforded ELLs opportunities to share their experiences through digital images (Hur & Suh, 2012). In this study, all the students had home computers and access to internet connections to complete their outside assignments. Though technology and connectivity are accessible in the classroom, not all students have access at home. Hur and Suh (2012) found that student liked the interactive lessons and digital creation, and technology motivated them and provided them with opportunities to practice speaking, writing, which is necessary to attend English proficiency. Their study provided learners with authentic opportunities to engage in learning through various media. However, it did not offer students without access other venues to acquire the same learning experiences. The lack of technological access for many ELLs should be accentuated to provide them with proper resources to achieve meaningful learning, improve language proficiency, and compete in the digital world. Using simulations to help ELLs understand the content area information is important, but these learners also require effective technological integration to acquire proficiency and compete in the marketplace.

The population of ELLs is rising at a consistent rate, but they are lagging behind their native English-speaking peers in almost every content area, including biological science. They obtain lower scores on standardized assessments compared to English speakers. Many ELLs are still working toward English language acquisition, but the school system requires them to take standardized achievement assessments to obtain a high school diploma. Time is one of the precious commodities needed to help them arrive at English proficiency where they can progress from mere conversational to the academic language needed to grasp science concepts. Several researchers suggested integration of literacy in inquiry-based learning to support ELLs with understanding science concepts and developing their second language proficiency with modifications (Stoddart et al., 2002; Zohar & Barzilai, 2013). Others recommended peer interaction through collaborative investigation, which is indicative of experiential learning and the constructivism framework in which learners are allowed to reach their Zone of Proximal Development (ZPD) through social interaction. The research regarding inquiry-based learning and integration of language in science instruction has proven beneficial to ELLs. They cannot learn science without language. Also, inquiry-based learning grants them the opportunity to acquire 21st-century skills needed for academic success. Technology permits students to work at their pace. Though technology grants ELLs time to work at their pace and has been proven effective when integrated in inquiry-based learning, research revealed that many students do not have access due to the digital divide among learners of various socioeconomic backgrounds. Also, the research also showed a significant disparity between African American students and ELLs regarding science simulations (Zhang, 2014). The gap that remains is how biology teachers use simulations to promote inquiry with ELLs. Seeking to close this gap is important because ELLs are lagging behind their peers in biological sciences and other content area needed for graduation and career readiness. While several studies explored the integration of technology in inquiry-based learning (Fullan 2013; Sox & Rubinstein-Ávila 2009; Ucar & Trundle, 2011), this proposed study explored how teachers use simulations, which include the integration of technology to foster inquiry with ELLs. Very little is known about the extent to which educators use biology simulations to support inquiry learning with ELLs. This proposed study may expand on current research by exploring how teachers use biology simulations to foster 21st- century skills. This study may add understanding to the gap that exists between African American students and ELLs when science simulations are used. Also, to examine whether biology simulations and the teaching that occurred around the implementation online simulations fostered biological concepts, global competencies and trans-disciplinary skills such as collaborative and problem-solving skills.

Teachers' Perceptions of ELLs in Science

English language learners (ELLs) already struggle with the English language, but teachers' perceptions of these students may further influence a students' ability to acquire the language because teachers' perceptions shape their instructional approach. ELLs have shown to be a consistently growing people in the country and the educational system. In 2013, about 22 percent of the school-aged children spoke a language other than English at home (Childstats.gov, 2015). Also, Doom and Schumm, (2013) noted that the population in the United States is expected to be more than 360 million by the year 2030. With the rise of ELLs in the classroom, it was important that teacher perceptions of students are well understood. Research has revealed that teacher perceptions affect their instructional practices (Britzman, 1998, 2012; Deemer 2004; Tsui, 2007). Like the students they instruct, teachers also carry their beliefs about teaching and learning to their classroom, and those beliefs arise from the teachers' personal experiences. These beliefs then convert into classroom pedagogical practice (Deemer, 2004). Britzman (1998/2012) agreed that teachers' preconceived ideas impact how they teach. Because teachers were once students, and are the product their educational experiences, their perspectives on teaching and learning are pre-established prior to entering the profession. However, with the school system and the population in the United States becoming more ethnically diverse, teachers view of ELL students is critical to student success. Serious concern is brought up in the literature regarding teachers' preparedness to meet the needs of ELLs because teachers' perceptions and experiences are not similar to ELLs educational experiences. This section of the literature review included a synthesis of the literature review of teachers' perceptions of ELLs, the importance of providing training for teachers of ELLs, and their perceptions of inquiry in science.

The first influence of teacher perceptions of the educational ability of ELLs is how these students are classified. Students are classified as non-English speakers with no distinction on their educational background from their native land; however, the term ELL represents a vast and diverse group of students. Burt, Peyton, and Adams (2003) explored the meaning behind the ELL label with no clear distinction on their educational background and recommended that labels should include the learners' primary literacy level. Echevarria, Short, and Powers (2006) agreed that the label does not account for the full array of experiences or the vast range of students with various levels of education and literacy attainment in their native language. One group of students may have achieved a high standard of scholarship, had resources, but lacked English proficiency; another group may be at the other end of the spectrum with limited resources and limited schooling. Similarly, not all English-speaking students arrive with the same educational background. ELLs bring their cultural and educational experiences that could be used to enrich their learning. Regardless of the socio-economic background and English barrier, ELLs are entitled to an equitable learning environment. Allowing all students equal access to a quality education is crucial to the sustainability of the educational system in the United States (OECD 2012). Teachers play a pivotal role in education; they are the change agents that shape the nature of the classroom environment, and their perceptions influence that role. Teacher perceptions of ELLs could help learners succeed socially and academically with the appropriate training. Understanding teacher perceptions of ELLs was a significant step, as it could impact English language proficiency of these students and their academic performance. It was important that teacher perceptions of ELLs and English learner needs were explored, and a clear distinction of their literacy levels was identified.

The next component that had an influence on the perceptions of teachers was their own personal lens through which they view their learners. The ability to connect with students at personal and cultural level could impact ELLs learning. Zumwalt and Craig (2005) noted that most educators in the United States are predominantly white, middle class, and female. In fact, Picower (2009) pointed out that 90% of teachers in the K-12 educational system are white. Per Ladson-Billings (2001), the life experiences of these teachers are so far different from their pupils that they find it difficult to offer culturally relevant instruction to students of diverse background. Furthermore, many educators have not acquired the training necessary to address the needs of the diverse student population within their schools. More content specific, science instruction for ELL has customarily been limited or inapt for the needs of the students (Buxton & Lee, 2014). These unresponsive approaches present difficulties to minority groups and immigrant learners who do not speak or have limited English abilities (Gay, 2002). Some teachers have reported that they found it challenging to teach a portion of the ELLs population

(Schall-Leckrone & McQuillan, 2012), and training programs targeting instruction for ELLs are meager and may not be valuable (Baecher, 2012). Teachers sometimes mistake cultural differences for cognitive or behavioral disabilities (Schroeder, Plata, Fullwood, Price, & Sennette, 2013). Teachers have reported a lack of connection with ELLs and have expressed that they feel inadequately prepared to teach ELLs (Polat, 2010; Tan, 2011). Furthermore, Rubinstein-Avila and Lee (2014) reported that secondary teachers' professional learning tends to cater to their specific content area such as mathematics, science, social studies, etc. rather than language acquisition. Unfortunately, cultural connection with ELLs is not considered an essential component of teacher professional learning. However, lacking understanding of the cultural experiences of their students and needs renders teachers ineffective at addressing the needs of their learners. This section of the literature included research related to professional development for teachers of ELLs and the perceptions of teachers of inquiry learning and English language learners. However, even with a lack of cultural connection with ELLs, research showed that teachers could benefit from professional development related to ELLs needs.

Importance of Training to Teacher Perceptions of ELLs

The training teachers receive is pivotal to changing their perceptions toward ELLs. Pettit (2011), Walker-Dalhouse, Sanders, and Dalhouse, (2009), Brown, Barkley, and Higginbotham (2011), and Doorn and Schumm (2013) examined teacher attitudes towards the ELL populations. Pettit (2011) found that teachers who acquire training in working with ELLs feel prepared. Also, the researcher reported that female educators believed that modifications are needed for ELLs more than male instructors. In a quantitative study of 11 schools and 149 math teachers, Pettit used a questionnaire to identify factors that impact teachers' beliefs. The result of Pettit's research showed training as an essential element, especially the lack of ELL strategies. Also, the perceptions of teachers were not significantly related to the percentage of ELLs in their classroom. Though the author acknowledged that math is not a language-rich content area, and instructional strategies are overlooked, ELLs require modifications in several content areas where language is used to make sense of the information they need to learn. In another study, Walker-Dalhouse et al. (2009) investigated preservice teachers' attitudes toward ELLs and their perceptions of how prepared they are to teach ELLs. They used a mixed-methods study to determine the impact of the perceptions of future teachers by having them participate in a pen pal letter-writing project. Preservice teachers were paired with middle school ELLs who were refugees. Educators and ELLs exchanged letters for ten weeks. The result revealed that teacher perceptions about their preparedness to work with ELLs improved. In another preservice teacher study, Brown et al. (2011) found diversity courses were another way to prepare preservice teachers to work with ELLs. They investigated if any change occurred in the attitudes of teachers after completing a Teaching Diverse Learners course. Based on pre-assessment, 46% of the 57 participants had minimal to no experience working with diverse learners; however, 96% of the participants revealed to have gathered substantial experience at the end of the course. The authors recommend mandatory courses on diversity and multiculturalism for all educators. Regardless of content area instruction, the understanding of the teachers of the background of their pupils could impact how the students learn. Doorn and Schumm

(2013) found comparable results in a mixed method study on teachers' attitudes regarding the language development and literacy of diverse students. Participants responded to a questionnaire on their personal attitudes toward and their preparedness to work diverse learners. The participants supported linguistic diversity and recommended bilingualism or multilingualism in schools nationwide (Doorn & Schumm, 2013). The results of the study are consistent with the mentioned studies. Teachers felt prepared after completing training to work with students of diverse backgrounds. Though teachers felt prepared after training, Hart and Lee (2003) concluded that additional professional development activities would better promote science literacy for diverse cultural learners.

Teachers, even of various content areas, are often asked to teach language skills within their content teaching, but this often conflicted with their traditional expectations of students learning content through completing independent work, reading texts, and listening to lectures; but such methods result in incomplete learning and gaps ELL proficiency growth and academic achievement (Eschevaria et al., 2004). Hart and Lee (2003) analyzed teachers' initial beliefs and practices on teaching English language and literacy in science and the impact of professional development on the beliefs and practices of teachers. The study focused on an urban population of six elementary schools, of which 57% Hispanic, 30% Black non-Hispanic (including 7.4% Haitian), 11% White non-Hispanic, and 2% Asian-American and Native American students. Districtwide, 70% of elementary students participated in free or reduced lunch programs, and 25% were designated limited English proficient. Teachers incorporated two instructional units on the water cycle and weather for two hours a week as part of the language and math lessons. Hart and Lee's three-year longitudinal study of 53 third and fourth-grade educators of a diverse student population revealed that teachers were able to teach concepts more coherently and provided more scaffolding to enhance understanding. Based on this study, more professional development activities are recommended to promote science literacy for diverse cultural learners. This study showed the significance of professional development in supporting teachers' instructional practices. Initially, teachers reported lacking in time and science knowledge, but equipped with instructional materials and scaffolding strategies to reach their students, they taught the two units along with their language and math contents. In another study, Batt (2008) took a different approach and focused on the perceptions of teachers who were known to work well with ELLs in rural public schools in Idaho. Batt wanted to learn what they perceived as their largest challenges and largest needs to improve ELL learning. Out of 161 participants of ELL educators, 157 were from Idaho and surrounding areas, which were from 26 countries. Based on survey results, not all teachers felt qualified to teach ELLs. Many felt frustrated with the lack of time, skills, and support. This study highlighted the importance of improving ELL education by improving dialogue between teachers and administrators on professional development on diversity in order to provide expertise to educate ELLs. Batt's study showed consistency with previous research, finding that teachers felt inadequately prepared and trained to teach ELLs in mainstream classrooms and desired more professional development (Hart & Lee, 2003). Given that the numbers of ELLs in the United States schools are predicted to increase (Doom & Schumm, 2013), professional development that prepares teachers and improves their perception of being able to meet these students' needs is crucial to English Language Learners' academic achievement. Equipping teachers with the appropriate training and instructional strategies to work with the ELLs population may prevent teachers from teaching ineffectively or subconsciously ignoring ELL's language and literacy needs instead of content areas.

Teachers' Perceptions of Inquiry in Science

Teacher beliefs are intertwined with their teaching practices, especially regarding the use of the inquiry approach. Traditionally, instruction is delivered through lectures (Eslamiyan, Saeedi, & Jarosz, 2013; Phillips, 2005). This method was ineffective and failed with students who had limited curiosity with learning. It also opposed the tenets of the framework of K-12 Science Education and the Next Generation Science Standards (NGSS). Rather than changing the lecture-based approach, Preston et al. (2010) reported that web-based lecture technologies (WBLT) are designed to digitally record lectures for delivery over the web. The lecture-based approach was shown to be ineffective (Mazur 2009); therefore, simply using the web to make lectures digitally accessible would not necessarily help promote learning. Deslauriers, Schelew, and Wieman, (2011) agreed that students make minimal learning gains from the lecture-based method in comparison to the active learning approach. To ensure equity and meaningful learning in which the students' diverse needs are addressed, inquiry-based instruction is recommended. The inquiry-based approach required learners to partake in active learning in science through grasping the nature of scientific inquiry and be engaged in the process. Besides, research has shown that students who have historically been classified as low achievers in science can thrive in inquiry-based classrooms (Blanchard et al., 2010). Based on these researchers' assertion, ELLs can succeed when teachers use the inquiry-based approach to teaching science. In a mixed method study that focused on investigating the perceptions of physical sciences (physics and chemistry) teachers on the implementation of inquiry-based learning at a diversity of high schools in South Africa, Ramnarain (2014) administered a structured questionnaire to 660 high schools comprised of 220 township schools, 220 suburban schools, 150 urban schools and 70 rural schools. Quantitative analysis of the questionnaire and qualitative analysis of interviews showed that teachers from all the schools agreed that inquiry-based learning engages learners in the process and fosters scientific skills, but teachers perceived the benefit of inquiry differently to grasping key concepts. Teachers at the township and rural schools preferred the didactic approach, whereas in the suburban and urban schools inquiry-based learning was embraced as being more effective and enable conceptual understanding. The author asserted that the lack of resources, large class sizes, and training in the township and rural schools limited the teachers' ability to implement inquiry-based learning effectively; therefore, they tend to revert and prefer the didactic approach. The author failed to mention that those teachers might also lack in content knowledge, which would explain why they returned to their comfort zone and continued teaching through lectures.

Perceptions of science teachers have also been compared to what scientists say are important for high school science students. In a qualitative study that used semi-structured interviews to explore the perceptions of 37 scientists from diverse science fields and 21 middle and high school science teachers, Taylor, Jones, Broadwell, and Oppewal, (2008) found that scientists and secondary teachers agreed that science inquiry learning fosters critical thinking and creativity. Both groups were polled on what students should know and demonstrate. Scientists agreed that science should be a more enjoyable content to learn, rather than just processes to be learned. Allowing students to design and execute their developed investigations while having fun, the "A-ha moments" these experts recommend would help students see the applicability of what is being learned to real life situations. Lacking proficiency in the English language, ELLs could achieve similar eureka moments when given the opportunity to learn via the inquiry-based approach. Scientists advocate allowing students to have fun during learning to stimulate their imagination, which in turns create more interest, excitement, and curiosity about science. However, educators' attempts at providing learners with a fun atmosphere for performing authentic scientific investigations that incite inquiry are often impeded by policies that require accountability via standard assessments to classify schools as high or low performing. Also, teachers' professional evaluations and salaries at times are tied to their students' standardized performance. Fun, curiosity, and creativity are not measured on a standardized test. Educators are left to decide how to teach and prepare their students for their future endeavors.

Other research showed that teacher perceptions are influenced by how educators perceive their effectiveness in the classroom with diverse learners. In a five-year study that examined 38 teachers' perceptions of their classroom practices compared to observed classroom practices, Lewis, Maerten-Rivera, Adamson, and Lee (2011) explored urban third-grade teachers' practices and perceptions in science instruction with English language learners. They used seven schools in a treatment group, and eight schools were in the control group. Lewis et al. (2011) included four domains of science instruction with English language learners: teachers' knowledge of science and content, teaching practices to support scientific understanding, teaching methods to support scientific inquiry, and teaching practices to support English language development during science instruction. Teachers participated in a professional development intervention to gain effective strategies to increase ELL students' scientific and literacy development. Lewis et al. (2011) explored two components: teachers' training with students from diverse background and scientific knowledge content to develop ELLs understanding of inquiry. Results from the questionnaire showed that teachers' practices for understanding were linked to practices for inquiry and English language development (Lewis et al., 2011).; whereas, the observations revealed that practices for understanding were associated with practices for inquiry, English language development, and teacher science content knowledge. However, Lewis et al. reported a negligible relationship between what teachers reported and observations of their practices. In developing ELL students' understanding of scientific concepts through inquiry, teachers are responsible for guiding their learners during inquiry learning to question, analyze data, and critical think (Bell et al., 2005). The National Research Council (2012) developed the eight key practices for learning science in grades K-12, which include communicating scientific explanations and support in language development for ELLs. Teachers could help them through scaffolding instruction to engage in higher order thinking activities (Bransford et al., 2000). The inquiry approach supports communication; it is not language dependent. Any intervention that is comprised of inquiry strategies that integrated language, reading, and writing could support language development. Research showed that additional training is needed to assist educators in connecting and educating English learners, and inquiry-based learning seemed to help them in reaching and teaching ELLs to engage in higher thinking and scientific inquiry learning. Though the teachers questioned their teaching efficacy, the research revealed that their perceptions of their teaching practices do not coincide with what the researchers observed of their teaching practices in the classroom.

In summary, how teachers perceive ELLs is critical to the academic success of English learners in the educational system of the United States. Teachers' perceptions of these students could impact both how they connect with their students and how they teach them. English learners bring diverse experiences, and their experiences could offer educators many opportunities not only to connect with them but also to influence language acquisition. Teachers' perceived shortcomings have identified in regard to multicultural education (Schall-Leckrone & McQuillan, 2012) and inquiry-based learning (Ortega, Luft, & Wong, 2013). However, research regarding teacher perceptions of ELLs suggested that teachers simply lack confidence in teaching these students, stemming from the lack of training received (Batt, 2008; Doorn & Schumm, 2013; Hart & Lee, 2003; Pettit, 2011). Furthermore, research showed that when the proper training is acquired, teachers' confidence to work with ELL improved (Pettit 2011). Teacher perceptions also shape their pedagogical approaches, and inquiry-based learning has proven effective with ELLs in learning science (Blanchard et al., 2010). Studies on teachers' perceptions of

ELLs have explored their connections with their students, their training or lack of professional development received, and their teaching practices, while others acknowledged educators' responsibility in guiding learners during inquiry-based learning to question, analyze data and derive solutions (Bell et al., 2005), and the need to support ELLs via scaffolding (Bransford et al., 2000). Though many studies focused on teachers' perceptions of ELLs, Baecher (2012) noted that the training programs targeting instruction for ELLs are minimal. However, very little is known about why these perceptions exist and how teachers perceive support to ELLs during the inquiry-based learning process. This gap is significant because ELLs need the support to acquire inquiry skills and English proficiency to succeed academically and socially. In this study, I explored how teachers perceive ELL strengths and weaknesses concerning inquiry-based learning. My study expanded on current research in understanding teacher perceptions of ELLs in science and any support they offered to ELLs during inquiry-based learning to help them improve scientific literacy and language proficiency. This study added understanding to the gap by exploring the perceptions of teachers on ELL strengths and weaknesses during inquiry-based simulated tasks.

Instructional Support for Inquiry Learning

Scientific knowledge and language learning are closely intertwined in helping ELLs to achieve mastery in both content areas. Education in the United States, at all levels, accentuates the significance of comprehensive English language learning to support science content learning and reinforces best practices. Inquiry-based learning offers ELLs opportunities to improve science content through thinking skills and communication skills (Huerta & Spies, 2016; Nargund-Joshi & Bautista 2016; Silva et al., 2013). Inquiry-based learning removes the focus from the traditional language-dense and lecture-based format and turns it into action, application, and experiential learning. Scientific concepts can be improved with content-based learning as well as through lab simulations. and hands-on laboratory practices. These techniques have been a critical part of science content knowledge. The intent of this study was to explore how biology teachers use simulations to promote inquiry learning with ELLs. Simulations could model real-world processes so that all students envision these processes without language barriers. However, it is important to know what are the best inquiry teaching practices and instructional support for ELLs. This part of the literature review will focus on these two components of the topic.

Best Inquiry Teaching Practices

Best inquiry teaching practices hinge on A Framework for K-12 Science Education and the Next Generation Science Standards (NGSS). Best practices have equity at the core, in which all students receive equitable opportunities to practice science (NRC, 2012). Acknowledging the cultural diversity of students and their wealth of prior knowledge, students must be allowed access to practice science based on their interests and experiences, which is significant to science improvement (NRC, 2012). In becoming scientifically literate, students need to partake in scientific inquiry practices that merge both knowledge and skill. The NRC (2012) devised eight practices as being fundamental for learning science in grades K-12:

1. Asking questions (for science) and defining problems (for engineering)

2. Developing and using models

3. Planning and carrying out investigations

4. Analyzing and interpreting data

5. Using mathematics and computational thinking

6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information. (p. 42)

Scientific knowledge is not gathered in isolation as sets of facts or procedures that hinder critical thinking; rather, it is acquired through the process of inquiry and curiosity. During inquiry, learners derive the best design using investigative skills, creative thinking, and evaluation of explanations to propose a solution (National Research Council, 2012). In other words, students are granted opportunities to learn like scientists do. The eight practices were used in the development of standards that drive science instruction (NGSS Lead States, 2013). The Next Generation Science Standards are developed from the core ideas of A Framework of K-12 Science Education. These standards provide educators with targets that students must be able to meet and tasks they must be able to do at the end of instruction.

Best inquiry practices require placing students' holistic learning at the forefront. In a case study examining teacher practices in two high school science inquiry units in the Portland metro area and the scientific explanations the students developed in their work samples, Hoffenberg, and Saxton (2015) qualitatively analyzed teacher instructional portfolios based on best practices in teaching science inquiry. Norgund-Joshi and Bautista (2016) blended the inquiry-based 5E model with the Sheltered Instruction Observation Protocol (SIOP) model in a three-session land pollution lesson. Coupling the two models offer instructional practices to support ELLs in learning science content and acquiring language proficiency. These studies offer pedagogical strategies to support ELLs in obtaining a holistic learning experience despite their language barrier.

Using the case study approach, Hoffenberg and Saxton (2015) investigated the relationship between pedagogical practices and explanation quality of two teachers with 63 students with approximately 20 percent ELLs. They found the five following factors in alignment with the NGSS that support students in constructing scientific explanations: content knowledge regarding science inquiry, balanced instructional techniques, prior experience conducting science inquiry, open-ended investigation topic, and clear goals for explanation construction aligned with relevant standards. Hoffenberg and Saxton explored several questions, including the effectiveness of current teaching practices in assisting students to meet the current science inquiry standards and how to support students in achieving the level of constructing scientific explanations as part of their inquiry-based experiences. These questions focused on best instructional practices in inquiry-based learning based on number 6 of the A Framework of K-12 Science Education and the NGSS mentioned above. Using two teachers' instructional portfolios and students' work samples to examine pedagogical strategies, Hoffenberg and Saxton evaluated teachers' instructional practices based on the Teacher Instructional Portfolio (TIP) framework that entailed three instructional practices: classroom roles, content and cognitive skills, and assessment for learning. Classroom roles instructional practice is student-centered, where the teacher guides students to create their knowledge. The content and cognitive skills instructional practice underline the integration of higher-order thinking skills, and the assessment for learning entails collecting data to improve teaching and learning. One of the two teachers, Sonia, who taught international baccalaureate biology, noted in her pedagogical reflection that her class spent time watching PowerPoint presentations, working both in pairs and collaboratively for labs, poster projects, and test review, videos, and class discussion. About 25% of her time was spent on inquiry activities, and she justified using more time on direct instruction because it is required to cover all the content. Inquiry teaching requires time, and students are at the center of learning. Also, the level of scaffolding was low in this study to benefit ELLs at understanding the content. In the other classroom, an educator named Joe, students partake in discussions of scientific explanation collaboratively during demos. The students were placed in a social construct that forced them to observe a phenomenon and challenged these students' current understand and develop further explanations to support cognitive thinking development. The results reflected the two teachers’ instructional styles; however, their instructions aligned with NGSS effective practice for teaching science inquiry. Their students’ sample reflected Sonia’s time spent on direct delivery and Joe’s students’ group work. Sonia's students fared well with the explanations and are expected to do better because they are in IB, which indicated that they had already acquired language proficiency. ELLs need more time and scaffolding instruction to support and elaborate on their explanation of scientific concepts. Adding strategies from the SIOP also support language acquisition could have placed the non-IB ELLs on an equal plane with their native English peers.

The SIOP model is a popular instructional framework that incorporates best practices for instructing ELLs. The model is made of several features that are categorized into the following eight stages: (a) preparation, (b) building background, (c) comprehensive input, (d) strategies, (e) interaction, (f) practice and application, (g) lesson delivery, and (h) review and assessment (Echevarria et al., 2004; Echevarría, & Short, 2011; Short, et al., 2012). The 5E model is also known as an instructional model consisting of the following phases: (a) engagement, (b)exploration, (c) explanation, (d) elaboration, and (e) evaluation (Bybee et al., 2006). Several studies coupled the SIOP with these phases of inquiry-based learning to support ELL students' science and language development. Bergman (2011) compared the stages of the SIOP Model with the characteristics of inquiry science and concluded that the two instructional models are complementary. He asserted that science educators could find ways around the conventions of teaching ELLs without forfeiting the inquiry process. Finding a synergistic approach to promote inquiry and language development is encouraged (Bergman, 2011). Norgund-Joshi and Bautista (2016) blended the inquiry-based 5E model with the SIOP on a three-session land pollution lesson. They used the 5E to help students build prior knowledge and then proceed to instruct novel concepts through engagement in exploration and investigation. Similarly, the SIOP was used to support the introduction of key terms to target language objectives. Nargund-Joshi and Bautista (2016) connected the engage stage of the 5E model in which educators elicit prior knowledge and the building background stage of the SIOP to introduce scientific concepts. During session one, which is the engage/building knowledge, students used T-charts to develop key terms from observing pollution from the classroom garbage can and assigned pictures. In the second session, which focused on exploration and is correlated to the comprehensive input, strategies, interaction, practice, student collaborated in groups of two to classify and categorize various objects that either increase or decrease land pollution at six stations. In the last session—which entailed elaboration and evaluate, practice/application, and review/assessment—students worked collaboratively to investigate types of waste at the school and develop a plan to help the school reduce its pollution. Students collected data and made recommendations to reduce pollution in their surroundings. These researchers incorporated the inquiry process by allowing ELLs to derive the best design using investigative skills, creative thinking, and evaluate explanations to propose a solute about land pollution. Furthermore, they integrated language using the SIOP to support ELLs content and language proficiency.

Instructional Support for ELLs

Providing instructional support to ELLs requires minimal modifications coupled with scaffolding strategies to drive science conceptual understanding. Scaffolding is defined as the practice of supplying appropriate support to assist students with tasks that are ahead of their current learning level of language proficiency (Zhang & Quintana, 2012). Support is given to learners early to facilitate learning and shifted to allow them to create their meaning (Jumaat & Tasir, 2014). Ricketts (2011) proposed a science fair project to engage ELLs in the inquiry process. Ricketts showed that with minimal modifications, educators could help ELLs master science concepts and improve their language skills. Using different phases within a project, ELLs were given questions to investigate on pendulums. The students chose their variables; however, to scaffold the instruction, procedures were provided to test the variables. ELLs had alternative approaches to present or communicate their thinking from drawings, charts, and simulations. This study was significant, for it showed that ELLs were capable of inquiry learning with minimal modifications. Teachers could encourage ELLs by not overwhelming them with language overload, but by using scaffolding strategies instead to engage them in inquiry learning, allowing them to acquire scientific and English language skills.

Regarding scaffolding strategies to assist ELLs with content and language development, Echevarria and Short (2011) offered educators a plethora of suggestions. The Sheltered Instruction Observation Protocol (SIOP) framework on language instruction allows educators to make content more understandable while allowing students to acquire language proficiency. The SIOP is made up of eight components: lesson preparation, building background, comprehensible input, strategies, interaction, practice and application, lesson delivery, and review and assessment. The model offers a framework for integrating language development with content teaching (Echevarria et al., 2004; Echevarría & Short, 2011; Short et al., 2012). Coupled with inquiry-based learning, the SIOP strategies have shown to make science comprehensible to ELL students. Echevarria, Richards-Tutor, Chinn, and Ratleff (2011) recommended teaching these strategies with fidelity to help students improve their academic language acquisition. As with any strategy, consistency is paramount. Because inquiry-based learning requires discourse, Lee and Buxton (2013) suggested that educators adjust their interactions with students according to their language proficiency. Teachers can utilize multiple explanations for the same concepts, paraphrase information when necessary, use clearer enunciation, and allow students time to process. When used effectively, scaffolding strategies play a significant role in fostering higher-order processing skills and build the conceptual understanding and communication skills of these ELLs.

During inquiry learning, scaffolding strategies assist ELLs to develop 21st-century skills. Reviewing the phases of the inquiry cycle, educators could orient students to the overall learning goal of their lessons. Bautista and Castaneda (2011) asserted that all students have the background knowledge to bring to the science classroom. Their prior knowledge should be activated to help deepen their science learning experiences. They also suggested that teachers modified the language instead of the science content. ELL students are entitled to the same instruction as the general student population. Through understanding the ELL students’ language proficiency, teachers can then develop teaching strategies that deepen science comprehension with the use of authentic visuals, inquiry, group collaboration, and discourse (Bautista & Castaneda, 2011). Educators can show equity by using a portfolio to document ELL students’ progress in English development and science comprehension. Alawdat (2013) examined the impact of e-portfolio for English as foreign language learners. Using data about the use of e-portfolio with English learners collected from 11 empirical studies over a period of two years, the researcher found that e-portfolios encouraged and improved students’ writing, language learning, assessment, and technical skills. Conversely, when compared to paper-based portfolios, the findings were not conclusive. Baturay and Daloğlu (2010) showed that paper-based portfolios are more efficient when tracking students' traditional assessment of grammar, vocabulary, and achievement test. On the other hand, e-portfolios provided valuable data on learners' writing and reading skills (Baturay & Daloğlu, 2010). In a similar study, Aliweh (2011) endeavored to improve English learners' writing and learning autonomy with the use of e-portfolios in a face-to-face classroom. The findings revealed no significant differences between traditional paper-based and e-portfolios regarding students' writing competence or learning autonomy. Shepherd and Bolliger (2011) confirmed Aliweh's study. They found that there is no significant difference between the requirements of paper-based portfolio and e-portfolios, but they also acknowledged that using e-portfolios fosters collaborative learning compared to paper-based portfolios. These studies revealed the effectiveness of using portfolios to assist learners in tracking their progress. Using portfolios provide learners the opportunity to own their learning by establishing learning targets and recognizing their strengths as well as areas that need improvement (Chang, Chen & Chen, 2012). Whether teachers use paper-based portfolios or e-portfolios, research showed that students' academic skills improved. Shaheen, Alam, Mushtaq, and Bukhari (2015) asserted that when strategies are used faithfully, students benefit: they perform better academically, their critical thinking skills improved, and they feel more confident. All these qualities enhance students' engagement in learning. Instructional support to ELLs is multifaceted, but the most effective strategies improve their language skills while simultaneously equipping them with 21st-century skills.

Other research focused on the balance of context-specific, generic, computer-based and teacher scaffolding during the teaching on scientific problems. Belland, et al. (2013) provided context for the skills that scaffolding substantiates, exploring the nature of scientific reasoning and how context-specific and generic skills are used and presented researched-based scaffolding strategies. Scaffolding involves an instruction figure providing active support to a learner to engage in an assignment that the student could not perform without help (Belland et al., 2013). The scaffolding process entails several elements: learners' interest, frustration management, feedback, modeling and questioning, and task selection. In one-to-one scaffolding, teachers provide generic, context-specific support. It is effective in helping students express and improve their thinking skills as well as learn contextual prompts related to scientific problems. Teachers' feedback is crucial in helping students develop critical thinking skills. However, basic techniques that involve decision making and memory use generic computer-based scaffolds. Since students' abilities vary, countless forms of scaffolding support multiple skills; therefore, a balance between the different types of scaffolding would better support ELLs higher order thinking and scientific reasoning skills.

Supporting ELLs with scaffolding strategies during online inquiry learning ensures both the content and technological engagement that may lead to effective learning. Zhang and Quintana (2012) warned that though students look busy when conducting online work, it does not necessary indicating that they are engaged or learning the content. To tackle the obstacles that students encounter during the online inquiry, the researchers developed a digital IdeaKeeper. IdeaKeeper is scaffolded software to assist students during online inquiry through planning, search, analysis and synthesis. Using a meta-analysis approach, also focusing on scaffolding strategies, Jumaat and Tasir (2014) investigated the types of scaffolding in an online learning environment. They categorized four types of scaffolding: procedural scaffolding, conceptual scaffolding, strategic scaffolding and metacognitive scaffolding. Metacognition allows learners to think about their thinking process; therefore, metacognitive scaffolding entails learners thinking during the learning process. Procedural scaffolding involves students using tools and resources, while conceptual scaffolding assists learners in making decision when considering what to learn. Strategic scaffolding offers an alternative approach to tackle difficulties in learning. Other scaffolding strategies mentioned in this study included technical support, content support, argumentation template, questioning, and modeling. However, metacognitive scaffolding seemed to be discussed the most in helping students develop thinking skills. Since higher-order thinking skills appeared to be vital to the inquiry process, placing more emphasis on metacognitive scaffolding was understandable. Using metacognitive scaffolding during active learning participation allowed students to process and reflect while creating meaningful learning experiences. These studies showed significant since they contributed to understanding the nature of the online inquiry as well as explored how to use scaffolded instruction and technological tools to support learning.

Instructional supports for inquiry learning range from asking questions that explicitly use learners' background experiences, making use of prior knowledge of new concepts, and analyzing data to construct scientific explanations to engaging in argument from evidence and obtaining, evaluating, and communicating information. A review of the literature highlights the importance of instructional support for learners during inquiry learning—including various types of scaffolding. Research regarding how to best support ELLs in learning science included, not only scaffolded instruction, but also inquiry-based learning with language integration. Also, computerized simulations allowed educators to model real-world processes so that ELLs could envision these processes without language barriers. The gap that remained was how science teachers scaffold when using online simulations labs to promote inquiry with the ELLs. This gap was significant because ELLs needed inquiry and 21st-century skills to achieve academic success. Furthermore, even as technology is advancing, a disparity still existed between African American students and ELLs using simulations compared to their Caucasian peers (Zhang, 2014). Some studies focused on instructional best practices by coupling the 5E model with SIOP (Norgund-Joshi & Bautista 2016). Others examined teachers' portfolios and students' work samples (Hoffenberg & Saxton 2015) and instructional scaffolding strategies using technology (Belland et al., 2013; Jumaat & Tasir 2014). However, my study explored how biology teachers use simulations to promote inquiry with ELLs and any additional help they provide to ELLs during their lessons. This study may expand on current research by improving practice in the fields of science education, technology in education, and English language learning. It may also add understanding to the gap by increasing knowledge on whether biology simulations and the teaching that occurred around the implementation fostered inquiry and 21st-century skills with ELL students.

Inquiry-Based Online Science Laboratories

Inquiry has had an impact on how educators teach science and how students learn science. Inquiry predominantly influences how students acquire scientific concepts. During inquiry-based instruction, students are active and independent partakers of the learning process (Lee 2011, 2012). Also, inquiry-based learning has proven to improve the ability of students to retain and apply what they learn, foster problem-solving and critical thinking skills, effectively collaborate with others, increase confidence and develop leadership and life-long skills (Harlen, 2013). According to the National Research Council (2012), developing scientifically literate learners requires incorporating the experiences of the students in the learning process. Scientific literacy also infers the ability to pose and evaluate claims based on evidence to arrive at conclusions. Learners need to perform inquiry tasks that merge both their knowledge and skills. The National Research Council (2012) created eight practices that are deemed fundamental for learning science in grades K-12. These eight practices have inquiry at the epicenter. All include components of inquiry that highlight how critical inquiry is to understand scientific concepts. In inquiry, students are expected to identify problems, create hypotheses or research questions, gather evidence or perform self-directed investigations or experiments. Also, they must conduct data analysis of the collected data, offer explanations or derive conclusions, evaluate their progress, and ultimately reflect on the inquiry process in its entirety (National Research Council, 2012; van Joolingen & Zacharia, 2009). Having students conduct inquiry activities simulates what real scientist do, insomuch that they develop a deeper understanding of scientific concepts. Although there are different ways to implement inquiry-based learning in science, some research showed that computer-based simulations, or virtual laboratory experiences, is one way of providing inquiry experiences for students (Furtak et al., 2012; Slavin, Lake, Hanley, & Thurston, 2014; van Joolingen & Zacharia, 2009). These researchers suggest that computer inquiry offers learners more venues to do science than traditional means. Computer-based simulations afford learners instant search, feedback, and multiple representations of models (Furtak et al., 2012). Furthermore, reviewed literature showed that science simulations are positively correlated with academic performance (Rutten et al., 2012; Zhang, 2014). This section will include reviews of the current literature science hands-on and virtual inquiry or simulations, how science teachers use online inquiry labs to support their students, and a review of teacher perceptions of online inquiry labs.

Science Virtual and Hands-On Inquiry Laboratory Simulations

Computer simulations could potentially offer students with opportunities to acquire scientific learning experiences not otherwise possible with hands-on laboratory practices. By definition, a computer simulation is a program that is run on a computer and uses detail methods to study approximate mathematical models of the hypothetical or real-world system (Winsberg, 2015), which includes animations, visualizations, and interactive laboratory experiences (Bell et al., 2005). It is a computer-based replica of a real laboratory experience (De Jong, Linn, & Zacharia, 2013). Simulations present students with visual or invented scientific phenomena and representation of non-physical concepts (Botzer & Reiner, 2005). Also, computer simulations could be used to assist scientists with making precise and general predictions (Winsberg, 2015). Some of these computer simulations are 3-D graphical worlds used to construct simulated immersive experiences. Many of these experiences would otherwise be unfeasible in the classroom due to the expensive equipment needed or length of time to conduct the investigation. Virtual labs allow students to virtually manipulate the type of scientific equipment that is not readily available to them in the physical classroom. Heradio et al. (2016) agreed that learners need hands-on experience with real equipment but acknowledged the rapid progress virtual world technologies. Also, Heradio et al. noted that the margin between what could be accomplished in the real world and the virtual is diminishing. Science education researchers and scientists consider computerized simulations to be promising technological tools for science teaching and learning (Clark et al., 2009). Computer simulations present potential benefits that could be effective in engaging students and fostering deeper learning (Clark et al., 2009) as well as enhancing scientific concepts (van Joolingen & Zachariah, 2009). Simulations support teaching and learning by allowing to students to interact with visual representations and manipulate experimental data sets. Using simulations, students explore, modify parameters, and deduce implications of data sets (Clark et al., 2009). Science simulations permit students to gain critical thinking and scientific skills while manipulating technological tools. Furthermore, Zhang and Li (2014) conducted a study of forty students who assessed realistic labs and open computer labs after 36 lectures, 18 homework assignments, and 6 lab assignments. The researchers found that simulations provide learners with the freedom to err and learn from their mistakes by repeating the simulations as many times as they need to understand the concepts (Zhang & Li, 2014). Computer simulations afford students with opportunities to use the same science equipment available to scientists not readily accessible in the classroom. Also, learners can repeat experiments, manipulate experimental data sets and learn from their mistakes. Students could perform the mentioned tasks within a shorter span of time, which is not possible in a physical classroom.

Though computer-based simulations permitted learners to use equipment not available in the classroom, proponents have voiced concerns, and students still have limited access to technological devices. Simulations have been described as computer-based: with the rise of tablets, smartphones and other devices that are used daily, perhaps simulations should be described as device-based. This notion is associated with bring your own device (BYOD) as part of the educational technology movement in K-12 (Raths, 2012). Harris (2012) acknowledged the impact of mobile technologies in society today has significantly influenced the education system. Technologies such as iPhones, laptops, and other mobile devices have noticeably made their presence in the classrooms. Computer-based or device-based simulations afford professionals in education other avenues to teach students; however, concerns about equity arise, not all students own a device. Based on a survey conducted by Project Tomorrow (2013), 80% of high students owned a smartphone and 70% had a laptop. Other concerns not related to technological availability include instructional effectiveness, lack of alignment to standards, need for teacher training, and limitations on time and schedule. All these factors present further barriers to implement simulations (Jones & Warren, 2011). Though simulations presented some concerns, the benefits to visually observed, manipulated, and developed conclusions from simulated scientific phenomena offered students opportunities to acquire scientific concepts and improved their learning experiences.

Virtual and hands-on laboratories. Laboratory experience is required as part of the science curriculum to reinforce science skills and concepts. According to the National Science Teachers Association (NSTA), labs must be at the core of the science curriculum to foster an effective understanding of science concepts at all grade levels for all students. Labs do not usually have similar goals. However, Singer, Hilton, Schweingruber (2006) stated that the goals of laboratory lessons must include mastery of the concept and acquisition of practical skills of the nature of science. De Jong et al. (2013) conceded that though the goals are different for physical and simulated labs, simulated lab can satisfy them. While physical labs are advantageous for supporting students' practical laboratory skills and providing them with a tactile environment not available in simulations, virtual labs effectively provide conceptual understanding because they contain fewer distractions and represent invisible phenomena (De Jong et al., 2013). Historically, physical or hands-on laboratory experience has been part of the curriculum; however, virtual or simulated-based laboratory have drawbacks while still offering benefits to science learning.

Several researchers outlined the advantages and disadvantages of virtual labs in comparison to physical labs. Figure 1 contains several benefits of virtual labs. Concerning benefits or advantages of virtual labs versus hands-on labs, researchers noted that simulated laboratory lessons could be completed in less time than traditional laboratories because students do not have to waste time gathering materials and equipment (Brinson, 2015; De Jong et al., 2013). However, this could be a disadvantage, because tasks such as gathering and setting up equipment and materials help learners gain organizational skills as well as tactile skills using the equipment (De Jong et al., 2013). Also, pertaining to cost, researchers noted the ever-changing of software could require high replacement cost (Brinson, 2015; De Jong et al., 2013; Potkonjak, et al., 2016; Pearson & Kudzai, 2015). Though simulations could be costly to create, once they are constructed, students have limitless opportunities to utilize them, so the cost per use could be minimal (Brinson, 2015; De Jong et al., 2013). Compared to hands-on laboratories, which could be quite expensive to build, maintain, and replace (De Jong et al., 2013) as well as instruments and equipment would also require highly trained technicians to maintain (De Jong et al., 2013). Furthermore, hands-on laboratories are less accessible compared to simulated laboratories. Brinson (2015) acknowledged that hands-on laboratory activities must be done when laboratory with a convenient time for both students and teachers, but simulated labs could be done at any location and time that meet students' needs and convenience. Also, students could make up missed labs or laboratory assignments when absent (Brinson, 2015), and since virtual laboratories promote collaborative and peer-supported learning (Bonser et al., 2013), they could work with partners. Moreover, simulated labs could accommodate the needs of a diverse population of students. Because they do not require the same motor skills students with motor control difficulties would find that simulated labs would provide them with same laboratory experience (De Jong et al., 2013). Also, computer animations could be tailored and adapted for students with visual impairment (Milner, 2001). De Jong et al. (2013) also noted that because simulations do not contain rigid time constraints they are beneficial to students who need more time. To that end, simulated laboratories could make laboratory lessons available to more diverse group of students like ELLs. Figure 1 summarizes the benefits of virtual or computer simulated labs.

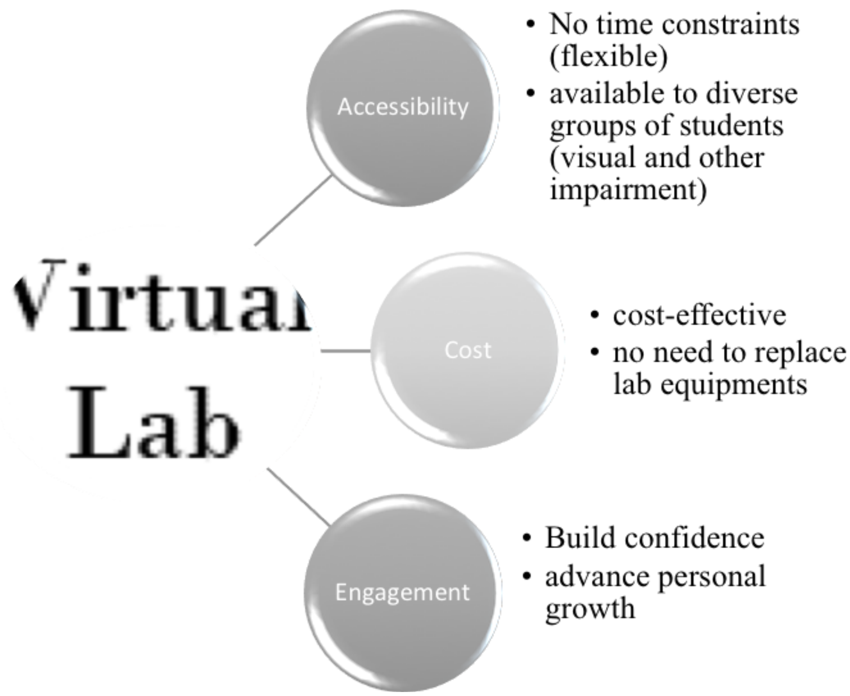

Figure 1. Benefits of virtual laboratories.

Depending on the goals of the science lessons and what teachers wanted to accomplish by having students experience virtual labs, likely both advantages and disadvantages would apply. Virtual labs present teachers with an interactive approach to support the laboratory experiences and enhance their students' interest in science. Renken and Nunez (2013) explored the benefits of simulated experiments versus hands-on or physical experiments with middle school students. A total of 147 seventh grade students were recruited from a life science classes in the Rocky Mountain region for this study involving two simple pendulum problems illustrating Newton laws of motion. Students observed both a physical apparatus and a computer simulation of the application of Newton laws of motion with pendulums. Participants were assigned randomly but in equal groups of 35 to perform one of four conditions of the experiment. Each student performed one of the following four conditions within the two approaches of observing slow motion replay and real-time replay simulations: 1) hands-on, real time replay, 2) hands-on, slow motion replay simulation, 3) real time replay, or 4) simulation, slow motion replay. The results indicated that there was no difference between the two approaches and the conceptual outcomes. However, learners were less likely to control their variables during the simulation exercise. Learners could have focused on the simulated environment and paid less attention to experimental control. The authors suggested that this might have been because students were so engaged in learning so that they placed less emphasis on the experimental process. Renken and Nunez noted a study from White (1993) in which students are entertained by computer simulations, perhaps causing them to change variables based on their enjoyment rather than experimental value. However, changing variables based on enjoyment did not negate learning. The researchers noted that the students were engaged in learning.

However, the Renken and Nunez (2013) results are inconsistent with Toth, Morrow, and Ludvico's (2014) study, which compared hands-on and virtual or simulation-based laboratories. Toth et al. noted that during hands-on laboratories, students' thinking was concentrated on the manipulation of the physical equipment; however, in the virtual labs, they directed their attention to the variables. Using the mixed method design with 32 first-year college participants, Toth et al. examined the characteristics of virtual and hands-on inquiry with bio-nanotechnology to separate DNA fragments using gel-electrophoresis. The researchers utilized a blended approach of hands-on and virtual laboratories to document the benefits of using virtual labs to support students with their knowledge development. The results indicated a significant advantage in that the virtual environment grounded students' learning and concepts as opposed to the hands-on experimentation. Toth et al. acknowledged that well-designed virtual labs contain visual clues to direct students' attention on the processes to gather results. Aside from what is contained within the simulations, teachers could scaffold by clarifying the learning targets of the intended tasks. Simultaneously, learners would gain opportunities to playfully explore the situations within the simulations while garnering critical laboratory experiences. Simulations or virtual labs provided students with an interactive environment to engage in learning science.

In several studies comparing hands-on or physical labs to virtual labs, researchers have found virtual laboratory experiments to be as effective as, if not more effective than, traditional hands-on laboratories. De Jong et al. (2013) reviewed the literature to compare hands-on to virtual laboratories regarding their benefits. Their research revealed that teachers do not believe simulated labs could replace hands-on labs. The National Research Council supports these teachers' views on simulated labs. According to Singer et al. (2006), The National Research Council acknowledged the advantages of simulated laboratories but takes the position that simulations should be utilized to supplement rather than replace hands-on laboratories experiences. Hatherly, Jordan, and Cayless (2009) agreed with the Council's findings and noted that nothing could replace the experience hands-on labs to provide students experiences in manipulating apparatus and equipment. They also noted that virtual labs should not be perceived as fostering a full laboratory experience unless such replacement is inevitable. However, De Jong et al. noted that virtual labs are comparable or excellent replacements for hands-on labs for teaching conceptual understanding and content knowledge because simulations contain fewer distractions. The researchers concluded that virtual labs could be acceptable substitutes for some hands-on labs, but they also recommended that simulated experiments be utilized when hands-on labs are not practical. In another study, Darrah, Humbert, Finstein, Simon, and Hopkins (2014) conducted a quantitative study investigating learning using virtual labs (Virtual Physics Lab) as a supplement to hands labs in an introductory physics course for 224 students from two universities using data collected and performing statistical analysis such a one-way ANCOVA and one-way ANOVA on the Postlab quizzes, lab reports, and tests from the participants. Their findings corresponded to De Jong et al. (2013) study that virtual labs showed to be as effective as the hands-on labs. Correspondingly, both Hawkins and Phelps (2013) and Winkelmann, Scott, and Wong (2014) conducted quantitative studies on traditional and virtual labs in chemistry. Hawkins and Phelps investigated the effectiveness of physical and virtual labs for teaching electrochemistry with 169 students. The analysis showed statistical significance between pre- and post-assessment of the two groups of 84 students who used the simulated laboratory versus the 79 students who utilized the physical laboratory. They concluded that virtual labs were equivalent to physical labs for teaching electrochemistry concepts; however, they advised that simulated labs are not equivalent in all situations. Winkelmann et al. (2014) studied high school performance using a popular multiuser online 3D virtual world chemistry lab called Second Life. A sample of five students completed lab reports on kinetics experiments from both virtual and hands-on experiments. Results showed no statistical difference with a 95% confidence level. Winkelmann et al. concluded that virtual labs may be acceptable alternatives to hands-on labs. The study had a small sample of five participants, which is not representative of the quantitative approach with 5% chance of discrepancies; however, the researchers referenced that a larger similar study is underway. The literature showed a consensus that virtual labs are appropriate to be used as alternatives to hands-on labs and could be as effective and hands-on labs depending on the goals of the lesson.

However, several other studies that compared hands-on to simulations found that students learn certain concepts better with virtual labs. Sarabando, Cravino, and Soares (2014) investigated how a computer simulation contributed to students' learning of physics concepts such as weight and mass. The researchers utilized a total of 51 seventh-grade students performed hands-on and computer-simulated experimental activities during the academic years of 2009-2010. In 2010-2011, the same intervention was used, this time with a sample of 142 seventh-grade students. Participants took a pre- and post-test after completing their experimental activities. Students either performed hands-on simulations, a blended hands-on and computer simulation, or computer simulation only. Sarabando et al. acknowledged that the role of the teacher during instruction is significant in explaining differences in students' performance during the treatments. They concluded that computer simulation support students in learning physics concepts of weight and mass whether used alone or together with hands-on labs. However, how the teachers implement the computer simulation played a role in its efficacy. In a related quasi-experimental design study, Chao, Chiu, DeJaegher, and Pan, (2016) compared how virtual and traditional teaching with sensor-based labs affect students' understanding of gas laws and kinetic molecular theory. A total of 30 students performed the intervention. After data analysis of pre-test and post-test, they concluded that students who performed the virtual labs made significant gains from pre-test and post-test. They outperformed students from the traditional intervention in almost all parts of gas laws and kinetic molecular theory. The study supported the idea that virtual labs promoted conceptual understanding in science.

Virtual and hands-on inquiry-based laboratories. Several researchers agreed that virtual schools could be as effective depending on the goals of the lesson. Clark et al., (2009) found that computer simulations present potential benefits that could be effective in engaging students and fostering deeper learning, and van Joolingen and Zachariah (2009) asserted that computer simulations enhanced scientific concepts. However, De Jong et al. (2013) noted that physical and virtual laboratories can accomplish related goals, such as studying the nature of science, fostering teamwork, and improving conceptual understanding. Also, combining the benefits of physical and virtual experiences and exploiting features from both could profit students (De Jong et al., 2013).

In addition to blending the features of both approaches, researchers also incorporated inquiry to immerse students in active investigations of scientific concepts. A huge amount of recent research advocates an inquiry-based learning approach as the most effective method, both for teaching and learning science (Bybee, 2014; Capitelli et al., 2016; Hiltunen et al., 2016; Weinburgh et al., 2014). So Toth et al., (2014) and Piraksa and Srisawasdi (2014) studies meshed with the blending of the hands-on lab and physical lab that included inquiry. Both of their studies were conducted using a blend of physical and virtual laboratories involving the inquiry-based approach. Using the blended approach that also included the inquiry-based method could aid students by promoting positive change in scientific understanding. Also, this approach could assist in developing scientifically literate citizens capable of tackling socio-scientific issues that would demand collaboration, problem-solving, decision-making skills, helping them to arrive at multiple solutions to complex situation that exist in nature.

Toth et al. (2014) conducted a mixed-method design and utilized comparative analysis to explore how the perceptual features of virtual and hands-on inquiry labs fostered students in developing experiments, analyzing data from experimental trials, and interpreting data acquisition with bio-nanotechnology. The researchers focused on two research questions in their comparison of virtual and hands-on laboratories. The first research question involved which learning condition is most effective after inquiry in supporting experimental design and conceptual understanding. The second one focused on what characteristics of students' inquiry advance with virtual or physical labs. The study involved three phases of inquiry with 150-minute-long laboratory sessions on the analysis of DNA from a crime scene. The first phase is referred to as the preinquiry phase, in which students are assessed. The second phase is called inquiry or inquiry-synthesis; in it, students begin either with the virtual lab or the hands-on lab with a worksheet before alternating to use the complementary lab with a worksheet. The third phase, post-inquiry, required students to complete the following elements: the design, the concepts after inquiry, and the post-instruction reflection instrument. Data analysis of the combined conceptual and design knowledge scores of the students after inquiry using ANCOVA revealed that virtual labs were more effective. However, the next analysis that focused on inquiry progress scores of the students revealed that their inquiry progress score was different depending on which lab was performed. Students who used the virtual lab performed with high inquiry progress scores and kept those scores towards the synthesis stage during hands-on lab, but those who started with hands-on had lower and inquiry progress scores and struggled with synthesizing their understanding. In a similar study using the same blended approach where a sample of 21 students examined real-world data, Toth (2016) found comparable results regarding the transfer of knowledge. This study also noted that students reported on their reflection instrument that virtual labs provided added graphics of the design, sped up the experimental design process, and allow them to err; however, the hands-on lab provided them with manual skills and allowed them to recognize various experimental errors. Results illustrated the advantages of using the blended approach. Though the study utilized a small sample of 32 students, their findings are significant in providing evidence to support the blended approach in inquiry-based learning.

In another study, Piraksa and Srisawasdi (2014) investigated the effect of the inquiry-based blended approach on the motivation of students taking physics. The researchers acknowledged that some of the concepts discussed in physics are invisible, complicated, and—at times—even boring (Piraksa & Srisawasdi, 2014). Using computer simulations have proven to engaged students in learning (Renken & Nunez, 2013). So as Srisawasdi and Kroothkeaw (2014) noted a computer simulation could serve as a tool for science learning, especially, when the activity involves scientific inquiry and the conceptual development in physics, like sound waves. Piraksa and Srisawasdi measured the intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation of 66 eleventh-grade students in physics learning with a 25-item questionnaire before and after performing open- and guided inquiry hands-on and virtual labs. MANCOVA was used to evaluate the effects of the intervention on which type of inquiry and test. They found significant difference on the motivation between guided- and open-inquiry learning of the students. The researchers noted a statistically significant difference between guided and open-inquiry learning process and the five kinds of motivation mentioned. The results are noteworthy and corroborated other research showing that motivation is directly linked to students' achievement (Denzine & Brown, 2015). Also, this study affirmed that the blended combination of hands-on and computer-simulated lab with inquiry-based lab is not only effective, but it also improves students' motivation. Other researchers noted a few reasons that demotivate students from learning science, such as poor-quality learning venues (Ramnarain, 2013) and negative learner attitudes (Juan, Reddy & Hannan, 2010). Merging inquiry-based learning with hands-on and virtual laboratory experiences provides students with opportunities to gain tactile skills and repeat scientific simulations as often as necessary to understand difficult concepts.

Science Teachers Use of Online Inquiry Simulations

This section of the literature focused on science teachers' use of virtual labs. It included information such as: when teachers use these virtual labs, how they use the virtual labs, and why they use them. Computer simulations have been proven to improve scientific process skills and allowed students to have a coherent understanding of scientific, and these simulations also aided students in constructing mental model (Suits & Srisawasdi, 2013). Inquiry-based simulations have been used to address conceptual learning problems in physics as an instructional approach in improving the scientific conceptual learning of students (Srisawasdi & Kroothkeaw 2014; Srisawasdi & Sornkhatha, 2014). Also, researchers found that simulation-based inquiry has helped students clarify misconceptions and improve conceptual understanding (Srisawasdi, & Panjaburee, 2015). With the integration of information and communications technology, the use of simulation-based software has started to become more main-stream within science education, and these simulations also offered science teachers opportunities to several ways to use inquiry-based virtual labs to promote science learning.

In relation to when teachers could use virtual labs, De Jong et al. (2013) noted that simulations have no time constraints, which would afford ELLs the time they need to gain laboratory experiences. Studies related to how simulations are used both in teaching and learning have been conducted for more than forty years (Smetana & Bell, 2012). Many of those studies revealed the effectiveness of virtual labs as tools in implementing scientific experiments without the boundary of space and time (Cappatore et al., 2015; Heradio et al., 2016; Karakasidis 2013). Reece and Butler (2017) conducted a study in biology with 300 participants using science, technology, engineering, and mathematics (STEM). Participants completed either face-to-face or virtual labs. Regarding the students demonstrating gains in the class through testing, they found no significant differences between the STEM students in the face-to-face and virtual laboratories. They asserted that virtual laboratories may provide an inexpensive alternative to resource demanding hands-on labs in biology. Also, Apkan (2002) agreed that simulations provide learners with the environment to reconstruct aspects of the real world that would not be feasible because of the level of complexity, how time-consuming, or how extremely dangerous these experiments to perform in the classroom environment. Furthermore, simulations allow unlimited number of students to perform the same experiment simultaneously (Brinson, 2015; De Jong et al., 2013). Moreover, Moore, Herzog, and Perkins (2013) reported that simulations are effective with large classes as they can perform their tasks without the frustrations of waiting on equipment. Teachers use virtual labs when they have large classes and they do not have access to readily available resources in the classroom to make scientific concepts comprehensible to their students.

Teachers could support learning of inquiry skills with virtual labs. Ramasundaram, Grunwald, Mangeot, Comerford, and Bliss (2005) designed simulations to afford learners the opportunity to partake in inquiry-based learning. The researchers' main target was to incite learners' higher-order cognitive skills during earth science geological field work that were complex to perform in the classroom. Using the simulation of 3-D soil landscape models, students could grasp spatial distribution of soils properties and relate the properties to topography. Simulation made abstract concepts more comprehensible. Moreover, the researchers asserted that the interactive learning tools went beyond what an educator could teach their students on a real field trip. Though simulations could assist teachers with inquiry-based learning, they lacked the presence or the realness, such as the lack of landscapes experiences such as the pests, and getting wet in the swamp. Presence is important in virtual labs because it gives students the perception of viewing virtual objects as actual objects Lee (2004). It also involves the awareness of being in and performing within a virtual environment, where the learner is focused on the virtual environment and disregarding the real environment (Schubert, T., Friedmann, F., & Regenbrecht, 2001). Schifter, Ketelhut and Nelson (2012) conducted a study that focused on presence during a virtual game. The researchers used virtual reality to assess science inquiry with a group of middle school students. In exploring the concept of presence with 154 sixth and seventh-grade students using the SAVE science research project, the researchers reported that students' experiences differed based on the post-module survey administered. The seventh graders reported a sense of presence more than the sixth-grade students. Schifter et al. posited whether the older students were more immersed or engaged in the virtual environment. This study is significant because it showed that teachers could provide students with the needed hands-on experiential learning by using inquiry-based virtual labs that have the concept of presence to engage them in learning science.

Several studies demonstrated that greater conceptual learning occurred when simulations are used for inquiry-based learning (Brinson, 2015; Chang & Linn, 2013; Dega, Kriek, & Mogese, 2013; Donnelly, Linn, & Ludvigsen, 2014). Brinson (2015) reviewed 56 articles on the effectiveness of traditional hands-on labs versus nontraditional labs, such as remote and computer simulated labs. About 87% of the studies revealed that nontraditional labs were equal to or superior to traditional laboratories in improving content knowledge. Also, all the studies that measured inquiry skills had comparable results. Likewise, Moore et al. (2013) reported the results of a study developed to gain insight into interactive simulation use during guided inquiry lessons in chemistry. Using the Physics Education Technology (PhET) implicit interactive simulations project at the University of Colorado, 80 students explored and experimented on Molecule Polarity without receiving instruction prior to performing simulations. Researchers then examined the learners' ability to utilize the simulation by evaluating the extent to which they explored the simulation, their discussions during simulation, and their perceptions of the simulation. Moore et al. reported that 22 groups explored an average of 18 of the 23 available features in Molecule Polarity. Regarding learners' perceptions of the simulation, 92% of the students reported that the simulation was useful for their learning, and they experienced either brief or no frustration during simulated exploration. The researchers asserted that the large classes could utilize interactive simulations created with implicit scaffolding through exploration without frustration. Also, PhET simulations could provide learners with the virtual learning environment that support guided-inquiry learning without explicit and channel students into productive inquiry while minimizing the need for explicit guidance. Sokolowski, Yalvac, and Loving, (2011) conceded that the PhET simulations enhanced learning and helped students immerse in the virtual learning experience and the inquiry process. Teachers could use the PhET Virtual labs to supplement learners' conceptual understanding with minimal guidance since the simulations included implicit scaffolding. The PhET simulations would benefit all learners—including ELLs—because the scaffolding component are already incorporated to support their language barriers. Kukkonen, Kärkkäinen, Dillon, and Keinonen, (2014) argued that when inquiry-based learning is coupled with simulations and proper scaffolding strategies, students could construct knowledge and achieve learning success. However, teachers must provide learners with the theoretical or foundational concepts to be reinforced or deepened using the simulations. These studies supported the idea that inquiry-based virtual simulations improve conceptual understanding of difficult concepts. However, these studies did not address whether or not simulations with appropriate scaffolding strategies support ELLs in understanding complex concepts.

In addition to enhancing conceptual learning, simulations could assist teachers in remediating misconceptions in science learning. In a study that focused on the 5E and the integration of simulations to remediate misconceptions, Sahin, Calik, and Cepni,

(2009) found that merging the 5E and simulations could produce conceptual change in students with different conceptions about liquid pressure. The Er Nas, Calik, and Çepni (2012) study corresponded with the Sahin et al. study on using alternate pedagogical approach to remedy misconceptions. Er Nas et al. focused on determining the effect of different conceptual change pedagogies embedded within 5E model. They conducted their study with 27 sixth-grade students on Heat Transfer. Using the pre-test/post-test questionnaire to collect data before and after teaching, they uncovered that using different conceptual change pedagogies embedded within 5E model was meaningfully effective in remedying the grade 6 students' alternative conceptions of heat transfer. Computer simulations could have contributed to the change by helping students visualize abstract concepts. Merging inquiry-based learning with interactive simulations could provide learners more opportunity to actively create conceptual understanding of scientific concepts and remedy the misconceptions.

Teachers use virtual labs to support students with language barriers and understanding. Aside from helping learners with conceptual remediation, computer simulations could offer ELLs with language acquisition. There is a significant disparity between minority students and ELL students regarding science simulations (Zhang, 2014). Also, research showed that science simulations are positively correlated with high income and the Caucasian population while negatively correlated to African-American population (Zhang, 2014). Most simulation and learning research to date has focused on the use of computers with ELLs and language acquisition (Peterson, 2011; Nemeth & Simon, 2013; Renalli 2008; Warschauer & Healey, 1998), while others merge inquiry and science simulations (Sahin et al., 2009; Er Nas et al., 2012). Renalli (2008) indicated that simulations support ELLs by fostering language use with meaningful contexts. Simulations contain images, sounds, and animations to help ELLs create meaning of the overall context. There exists a dearth of research on ELLs and science simulations studies, more specifically biology simulations with ELLs. Rutten et al. (2012) found robust support for simulations in improving science teaching and learning. Simulations are used to complement laboratory experiences, foster learner's discovery, and deepen essential science concepts (Rutten et al., 2012). Also, the use of simulations has proven to provoke students' actions and encourage them to make choices that could expose and challenge learners' misconceptions, while simultaneously providing opportunities for remediation (Lindgreen & Tscholl, 2014). Based on the benefits that science simulations provided science learners, ELL students stand to profit when they have equal access to use them, as well as when scaffolding and remediation are offered to help them extend scientific concepts.

In a study using simulations and English language learners, Davis and Berland (2013) conducted primary empirical research to evaluate the possible merits and difficulties related to participatory augmented reality simulations with English learners in K-12 science classes. The researchers referred to participatory augmented reality simulations as PARS. These simulations add real components to the virtual environment with audio, visual cues, concrete objects (Davis & Berland, 2013). Davis and Berland noted the significance of completing this study with the ELL population because they are at greatest risking of dropping out of school than any other group, and PARS could facilitate ELL comprehension and understanding. PARS offered science classrooms new possibilities to assist learners with better conceptualize scientific processes. Also, it also contains graphics that boost scaffold learners' comprehension. Engagement is an essential part of learning, and PARS permitted learners to be engaged through interaction, technology while simultaneously challenged them via the problem-solving aspects. The English language presents an obstacle to ELLs in content area classes, but PARS appear to support language use through a scaffolded environment. This is supported by Renalli (2008), a study that revealed an increase in students' vocabulary knowledge when simulations were used. Davis and Berland pinpointed elements of PARS that focus on components for effective instruction of English learners such as engagement, collaboration, and language. They found that additional research into the use of PARS in science pedagogy may profit ELLs by highlighting the key components of PARS and best practices for ELLs instruction. Though simulations have proven to support laboratory skills, they should not replace hands-on experimental practice; rather simulations could play a significant role in supporting prelab activities.

Technology enhances learning, but teachers' contributions to the quality of the instruction play a significant role in the learning process. Matuk, Linn, and Eylon (2015) noted the significance of teachers' involvement in curriculum design and in maintaining the relevance of technology-enhanced learning resources. In a similar study regarding the effectiveness of simulations, Linn, Chang, Chiu, Zhang, and McElhaney (2010) identified key design principles to support learning. First, simulations should provide individualized support and be void of irrelevant and distracting instructional interventions. Second, simulations should contain meaningful scientific content and adjust activities to align to students' progress. Third, simulations must incorporate scaffolded instruction to address learner's needs. These principles are significant, as they integrated key features of effective instruction as well as included support for ELLs. ELLs could acquire the language and effectively learn the content area concepts in science while manipulation different technological scenarios to deepen their conceptual knowledge using online simulations.

In relation to how teachers use virtual labs, research has shown virtual labs to be used in various modes in terms of feasibility, stand-alone, and alternatives for hands-on. Several researchers present evidence that supports virtual labs as potentially sufficient replacements for hands-on (Altalbe, Bergmann, & Schulz, 2015; Lang 2012; Myneni, Narayanan, Rebello, Rouinfar, & Pumtambekar 2013; Zacharia & Olympiou, 2011). In two separate studies, Altalbe et al. (2015) and Myneni et al. (2013) asserted that virtual labs have advantages that would replace hands-on laboratory experiences. Altalbe et al. focused on thirteen learning objectives for engineering laboratories to measure the effectiveness of virtual engineering laboratories. Except for the psychomotor and sensory awareness, in which the results revealed that physical laboratories are more effective because it provided students with sensory and situational awareness, which a virtual lab could not produce); all the other objects could be replaced with virtual labs (Altalbe et al., 2015). Their results substantiated De Jong et al. (2013) study that the goals of lessons determined whether hand-on or virtual labs would be more effective. Myneni et al. utilized a Virtual Physics System (ViPS) to help students master energy and force in the context of pulleys. The researchers noted that these simple machines are difficult to build and use in the real world. Students used the ViPS as the virtual environment and constructing and experimenting with real pulleys. Myneni et al. evaluated the efficacy of both environments and concluded that not only was ViPS effective in correcting students' misconceptions, but virtual experimentation in the ViPS was more effective than real experimentation with pulleys. These two studies provided evidence for using virtual labs to replace hands-on labs.

However, other researchers advised against replacing certain hand-on labs with virtual labs. Davis and Berland (2013) acknowledged the significant of simulations in promoting laboratory skills, but they did not recommend simulated labs to be used as replacements for hands-on experimental practice. They suggested using simulations to support prelab activities. Their study showed that simulations offer teachers new possibilities to assist students to better conceptualize scientific processes, and they also contain the graphics to promote engagement and comprehension. Dewprashad and Persaud (2015) utilized the flipped classroom approach to evaluate the effectiveness of using simulation as prelab activities. Students had to read, view diagrams and videos, and perform the prelab simulations describing the setup of a concept in organic chemistry that required the apparatus for Comparison of Simple and Fractional Distillation in the lab. After completing the prelab activities, students were required to set up the apparatus. The results indicated that the students set up the apparatus in the classroom within fifteen minutes. These researchers showed that teachers could use simulations as prelab activities instead of replacements for tactile experiments. Makransky, Thisgaard, and

Gadegaard (2016) conducted a similar study with 189 undergraduate students who used a vLAB at home as a prelab focusing on streaking bacteria on agar plates in a virtual environment. Makransky et al. used pre-test and post-test to determine how much understanding students had of microbiology. They concluded that vLABs prepared the students well for a physical lab activity in microbiology.

Additionally, evidence from other studies directly compares simulated or virtual labs with hands-on labs and proves them to be as effective as or more effective (Brinson, 2015; De Jong et al., 2013). Other results indicate that blending these two laboratory approaches would benefit science teaching and learning (Toth, 2016). However, teachers play a significant role in the implementation of labs. Teachers are the leaders of their classrooms. As such, they utilize certain standards to determine the target of their lessons and which laboratory approach would help meet the needs of their students. Ultimately, the teachers may decide when to use virtual labs, why to use virtual labs, and how to use them to support science learning.

Science Teachers' Perceptions of Simulations and Virtual Labs

Several studies focused on teacher attitudes regarding simulations. Many educators reported barriers to implement simulations, including concerns about instructional effectiveness, lack of alignment to standards, lack of access to technology, and time constraints (Jones & Warren 2011). In a study using Multi-User Virtual Environment (MUVEs), Metcalf, Kamarainen, Grotzer, and Dede (2013) examined teacher perceptions of using MUVEs has an effective platform to engage learners in the learning process. Also, the researchers explored teachers' perceptions of implementation feasibility, alignment with learning objectives, and perceived value. They utilized surveys and interviews to gather their data from 16 educators who used a similar program based on the environment called EcoMUVE. The curriculum is inquiry-based: students investigated research questions in virtual ecosystems before gathering their data over time while working in teams. Also, students worked individually in 3-D immersive environment to chat and share data. Regarding feasibility, 14 of the 16 teachers reported that that platform is feasible with access to technology. In the post interviews, two educators noted that students had the opportunity to enter the virtual world and manipulate real world situations, applying scientific thinking and concepts in a novel but meaningful way. Standards alignment was also examined, and educators agreed that critical thinking was incorporated and was needed to understand the dynamic relationships within ecosystems. Using a scale of 1-5 regarding teachers' perceptions of the impact on student engagement and inquiry learning, with 1 being poor and 5 excellent, student engagement earned an average of 4.3 out of 5, science content 4 out 5, while inquiry learning was 4.3 out of 5 for student engagement. These results are significant regarding engagement and inquiry learning. They show that students can be actively engaged in the inquiry learning process. Teachers' perceptions of simulations like EcoMUVEs were encouraging. Educators perceived that the curriculum was feasible, aligned well with the standards, and engaged learners in learning science concepts using the inquiry-based method.

In another study, Achuthan, Sivan, and Raman (2014) explored the perceived impact on use of virtual laboratories (VL) and simulations as a teaching aide in science education using the technology acceptance model as their theoretical framework. The researchers provided a focused workshop on virtual laboratories to faculty from 20 polytechnic institutes. Teachers were immersed in learning about virtual laboratories for its use as a teaching aide using two physics experiments. It consisted of an introductory session, a demonstration of the virtual laboratories' experiments, and hands-on training. Access to technology and connectivity posed an inconvenience in performing simulations. Achuthan et al. collected results using a survey with a mix of multiple-choice questions. The researchers utilized descriptive statistics in reporting the perceived usefulness of virtual laboratories. Compared to using a textbook to explain an experiment on a spectrometer, teachers reported that using VL took less time, from 30 minutes to less than 10 minutes. Teachers' perceptions of VL were positive. They noted that using simulators seemed to provide students with a better understanding of the concepts and take less time; best of all, close to 100 percent of the educators felt that the simulator would make the concept more comprehensible. These results showed promising and significance, as teachers are at the forefront of quality instruction. Educators' perceptions of simulations would influence how they used them and their impact on students' learning.

Additional studies have shown that teachers' perceptions could affect the implementation of simulations in the science classroom. Computer simulation alone is not enough in promoting students' understanding and conceptual change (Srisawasdi, 2012). Kriek and Stols (2010) noted that educators' existing perceptions could restrain implementation of technology in their classroom. Therefore, teachers' beliefs need to be understood, because beliefs undergird the decision-making processes. Ertmer, et al. (2012) agreed that teachers' beliefs are viewed as a key factor when seeking to integrate technology in learning. In a study investigating the impact of a single-group pre-test/post-test design regarding the use of simulation in science teaching on primary school preservice teachers, Lehtinen, Nieminen, and Viiri (2016) used a sample of 36 participants. Also studied were technological, pedagogical, and content knowledge (TPACK), as well as teachers' views on the usefulness of simulations in science education. Finally, the study evaluated their disposition toward incorporating simulations in their classroom. Of the 36 participants, only one teacher had used simulations in the classroom. The intervention had two groups and was implemented during 8 weeks with 90 minutes' lessons on inquiry-based teaching of science simulations from PhET simulations. The results revealed a low positive correlation on preservice teachers' views on the usefulness of simulation in science. Data analysis involved the Pearson's correlation with a statistically significant correlation at the .05 level. Similar results were reported regarding the TPACK framework and the preservice teachers' disposition about integrating simulations into their science teaching. This study provided statistical data but could have also included interviews results on teachers' beliefs as the researchers suggested. However, the results showed that teachers' views on the implementation of simulations could affect how they are used in the classroom.

To better prepare ELLs for science, technology of the 21st century, and the global community, science teachers could integrate technology, specifically simulations and inquiry-based teaching in their instructional approach. Literature on science simulations or virtual labs range from positive correlation with academic performance (Rutten et al., 2012; Zhang, 2014) to using computer simulations to effectively engage students and foster deeper learning (Clark et al., 2009). Research regarding how best to support ELLs in learning science with simulations is minimal; several researchers focused on simulations to assist ELLs with language acquisition (Peterson, 2011; Nemeth & Simon, 2013; Renalli 2008; Warschauer & Healey, 1998) but do not include teacher perceptions related to teachers using simulations with ELLs-This gap is important because teachers' perceptions could affect the implementation of simulations in the science classroom. Also, it would help in understanding how they perceive ELL students' strengths and weaknesses in relation to inquiry learning when simulations are implemented to better understand the phenomenon of ELL students' use of inquiry-based simulations in science education. While some studies explored incorporating simulations to support ELLs with language acquisition (Peterson, 2011; Nemeth & Simon, 2013) and the perceptions of mainstream science teachers on the use of simulations (Ertmer et al., 2012; Lehtinen et al., 2016; Metcalf et al., 2013), this study explored science simulations with ELLs pertaining to biology and how teachers perceive ELL students' strengths and weaknesses in relation to inquiry learning when simulations are used. This study expanded on current research by adding to the dearth of research on using simulations with ELLs in science.

Summary and Conclusions

Chapter 2 included the literature review of various elements that make up this study, including topics such as English language learners, inquiry-based learning, and simulations. At the beginning of the chapter, a synthesis of the literature review regarding ELLs revealed that they are the fastest growing group of students in the United States and estimated to rise (Ardasheva et al., 2015; Fayon, et al., 2010). The following topics were also addressed in the literature review including the conceptual framework for this study: (a) history of Inquiry-based science pedagogy, (b) English language learners, (c) science teachers' perceptions of ELLs in science, (d) instructional support for inquiry-based labs, and (e) inquiry-based online science laboratories.

The literature review contained what is known from the various themes and the gaps. Regarding ELLs and inquiry learning, studies suggested the population of ELLs in the school system will continue to rise (Ardasheva et al., 2012; Fayon, et al., 2010). Some researchers suggested incorporating language support during instruction to help ELLs succeed academically (Echevarria et al., 2004; Echevarría, & Short, 2011; Short et al., 2012; Gawne et al., 2016). However, other researchers recommended the integration of literacy in inquiry learning to help ELLs grasp science concepts and develop their second language proficiency with minimal modifications (Lara-Alecio et al., 2018 Stoddart et al., 2002; Zohar & Barzilai, 2013). These studies are supported by other researchers who discovered that effective language development method for ELLs had yielded positive results using inquiry-based learning in math and science instruction (Weinburgh et al., 2014; Capitelli et al., 2016). Still, the ELLs are lagging behind their native English-speaking peers in almost every content area, including biological science. This proposed study will increase understanding by exploring how biology teachers support ELLs in learning inquiry skills.

Concerning instructional support and online simulations, reviewed literature showed that using scaffolding strategies promote inquiry learning. Teachers assisted students with tasks that are ahead of their current learning level of language proficiency (Zhang & Quintana, 2012), providing them with early support to facilitate learning and shifting to allow them to create their meaning (Jumaat & Tasir, 2014). Also, Norgund-Joshi and Bautista (2016) suggested blending the inquiry-based 5E model with the SIOP. Regarding online simulations, research showed that they are positively correlated with academic performance (Rutten et al., 2012; Zhang, 2014). Several studies demonstrated that greater conceptual learning occurred when simulations are used for inquiry-based learning (Brinson, 2015; Chang & Linn, 2013; Dega et al., 2013; Donnelly et al., 2014). However, Zhang (2014) noted the disparity that exists between African American students and ELLs regarding science simulations. Research related to how to best support ELLs in learning science with simulations is minimal. This proposed study explored how teachers use simulations which include the integration of technology to foster inquiry with ELLs to improve practice in the fields of science education, technology in education, and English language learning.

Teachers play a pivotal role in education; they are the change agents that shape the nature of the classroom environment, and their perceptions influence that role. Teacher perceptions of ELLs could help learners succeed socially and academically. Research has revealed that teachers' attitudes affect their instructional practices (Britzman, 1998, 2012; Deemer 2004; Tsui, 2007). However, some teachers have reported that they found it challenging to instruct a portion of the ELL population

(Schall-Leckrone & McQuillan, 2012), and educational programs targeting instruction for ELLs are insufficient and may not be helpful in equipping them with the needed skills (Baecher, 2012). Furthermore, teachers sometimes mistake cultural differences for intellectual or behavioral disabilities (Schroeder et al., 2013). Moreover, teachers have reported a lack of connection with ELLs and feelings of inadequacy when engaging with ELLs (Polat, 2010; Tan, 2011). Many studies focused on teachers' perceptions of ELLs and the lack of training programs. However, very little is known about why these attitudes exist and how teachers perceive support to ELLs during the inquiry-based learning process, which is an additional gap explored in this study.

Contained in this chapter was a description of literature search strategy, the conceptual framework of this study, and a detailed literature review of English language learners, inquiry-based learning, online simulations, and teachers' perceptions. In chapter 3, I discussed the qualitative case study research methodology and provided an explanation of the research design and rationale. I explained the role of the researcher, participant selection and procedures for recruitment, and instruments for data collection. Also, I addressed ethical concerns related to this study and issues of trustworthiness in connection to credibility, transferability, dependability, and confirmability.

Chapter 3: Research Method

The purpose of this study was to explore how biology teachers support ELLs when using biology simulations to promote inquiry learning in biology classes in a large urban school district in the southeastern region of the United States. To achieve this purpose, in a qualitative case study, I explored how biology teachers support ELLs with biology simulations to foster inquiry skills using the EQUIP model, the TUSI model, and the constructivist theory (Vygotsky, 1978), specifically the ZPD. Qualitative data were gathered through interviews, lesson documents, and computer simulations.

Chapter 3 is organized into five sections. These five sections are employed to explain the use of the methodology in the study. Section 1 is the Research Design Rationale, which contains the research questions, central phenomenon, and the research approach. Section 2 covers the Role of the Researcher, in which I discuss my responsibility in the context of data collection and analysis. This section will also include any biases or ethical concerns. Section 3, which is the Methodology section, is comprised of the data collection instruments and procedures, the selection of participants, and the process for analyzing data. Section 4 deals with Issues of Trustworthiness and I discuss the issues of credibility, transferability, dependability, confirmability, and ethical procedures. The last section contains a summary of the key points and a transition to Chapter 4.

Research Design and Rationale

The central question and the conceptual framework guided the study. The central research question, component questions, and the related subquestions were derived from the conceptual framework and the literature review. Included in the Research Design and Rationale section are the questions, the central phenomenon, the rationale for the methodology selected, and considerations given to other methodologies of this study.

Research Questions

The research questions for this study were based on the conceptual framework and literature review.

Central research question: How do biology teachers support ELL students when using online biology simulations to promote inquiry learning?

Component questions and related subquestions:

1. How do teachers perceive ELL students' strengths and weaknesses in relation to inquiry learning using simulations?
2. How does teacher scaffolding influence the level of inquiry for ELL students?
   - 2.1. How do teachers describe their scaffolding to support ELL students' inquiry learning during the implementation of biology simulations?
   - 2.2. How do teachers use scaffolding in online simulations to make scientific inquiry understandable to ELL students?
   - 2.3. What level of inquiry do teachers address in biology simulations for ELL students based on the indicators of the EQUIP framework?

Rationale for Research Design

The research approach for this study was qualitative. This approach was fitting because qualitative research entails an understanding of how people make sense of their experiences (Merriam & Tisdell, 2016) and connect meanings to the social world (Miles et al., 2014). Overall, qualitative researchers seek to understand "(1) how people interpret their experiences, (2) how they construct their worlds, and (3) what meaning they attribute to their experiences" (Merriam & Tisdell, 2016, p.24). According to Merriam and Tisdell (2016), meaning is not found but constructed from experiences. For this study, the qualitative approach was selected because it focused on the meaning and understanding that biology teachers attributed to how they supported ELL students when using biology simulations to promote inquiry learning. The qualitative approach included open-ended interview questions to explore participants' experienced situations in the natural setting and to identify the experiences of participants that answered the research question (Yin, 2014). This study included semistructured interviews to explore participants' perceptions of ELLs during inquiry learning. Patton (2015) identified qualitative research methods as useful approaches for researchers seeking to understand a phenomenon of interest in-depth when numerical data or variables creation's connections are not present or uncertain. Qualitative inquiry has allowed research practitioners to capture and make sense of diverse perspectives of events (Patton, 2015), unlike the quantitative approach that requires quantifiable evidence with statistical data measurements to examine relationships between different variables (Maxwell, 2013). Therefore, an exploration to gather data that provide in-depth understanding in contextual constructs with a conceptual framework that was constructed would not be appropriate for a research study that examines correlations between hypotheses.

The multiple case study design was selected for this study. Yin (2014) offered a definition of case study that has two parts. In the first part, Yin defined the scope of a case study as “an empirical inquiry that investigates a phenomenon in depth and within its real-life context especially when the boundaries between the phenomenon and the context are not clearly evident” (p. 16). Yin expanded this definition because case studies phenomenon and context are not always clear in real-life settings. In the second part of the definition, Yin included the features of case study by stating,

> Case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide collection and analysis. (p. 17)

For this study, the uniqueness of the case study design that Yin noted explored the boundaries between the phenomenon and the context that were not sharply distinguishable. The phenomenon in relation to this study was defined as ELLs using online biology simulations in the classroom, and the context was defined as biology teachers instructional support to promote inquiry-based learning when online simulations are used. Creswell (2013) presented a case as bounded system. Miles et al. (2014) added that the case is “a phenomenon of some sort occurring in a bounded context. The case was in effect, your unit of analysis” (p. 28). This study was composed of two cases or bounded systems: two high schools from a large school district in the southeastern region of the United States. Using two cases provided greater variation across cases and more compelling interpretation of the phenomenon. Miles et al. agreed that looking at more cases “can strengthen the precision, the validity, and the stability of the findings” (p. 33).

Merriam and Tisdell (2016) added that multiple cases improve external validity of the findings. The qualitative multiple case study design was selected based on the conceptual framework, which includes the constructivism perspective, and the purpose of the study as presented in its focus and the research questions. However, other designs were considered but rejected in place of the case study approach, which provided an in-depth description and analysis of the mentioned bounded system.

Consideration of Other Designs

Various other qualitative designs were considered for this study but were ultimately rejected. The phenomenology design was rejected because it requires capturing the essence of lived experiences, and “interview is the primary method of data collection” (Merriam & Tisdell, 2016, p. 27). However, the case study design provides researchers with multiple sources of evidence to arrive at understanding of the phenomenon of ELLs using online biology simulations in the classroom. In addition, the phenomenology design did not befit the purpose of this study because the affective and emotional experiences of teachers were not explored. The ethnographic design was also rejected because it did not align with purpose of this study. Patton (1990) noted that ethnographic studies center on understanding the customs of a culture. Northouse (2010) added that ethnographic researchers record the customary interactions, acquired attitudes, morals, and standards for a group of individuals. Ethnographic studies are anthropological, in which the ethnographic researchers seek to acquire a detailed and holistic view of a culture and are obliged to be immersed with the group being studied for an extended period to understand the group’s lived experiences (Creswell, 2007). The aim of this study was not to be immersed in a setting and analyze data to provide a cultural interpretation of the ELLs using online biology simulations.

In addition, both narrative inquiry and ground theory were rejected as research designs for this study after due consideration. The narrative design permits researchers to analyze individuals' stories seeking revelation of their worldviews (Patton, 1990). It is an interpretive approach of storytelling that focuses on making sense of events and actions in individual's lives and aims to produce knowledge of individuals' experiences (Yang, 2011). One of the component questions derived from the conceptual framework and the purpose of the study is to understand teachers' perceptions of ELL students' strengths and weaknesses in relation to inquiry learning; however, sources of data were interviews, documents, and biology simulations rather than stories or experiences in the first-person account. Grounded theory would not have been an appropriate design either. Creswell (2013) noted the goal of grounded theory as a qualitative method is to "generate or discover a theory…for a process or an action" (p. 83). The intent of this study differs from the ground theory approach. According to Patton (1990), grounded theory is central to qualitative research. He added that using comparative analysis and fieldwork can lead to the emergence of a theory (Patton, 1990). The intent of this study was not to use this process to derive a theory. Regarding qualitative case studies, Hammersley (2012) stated that case studies must be drawn from existing theories because they seldom generate new understanding entirely. However, through case studies, researchers could become cognizant of the shortcomings within current theories rather than developing a theory that is already known (Hammersley 2012). In this study, rather than collecting data to develop a theory, the blending of the constructivism perspective, the EQUIP model, and the TUSI model provided the guiding framework. Data were also gathered to explore a phenomenon, not to generate a theory.

Role of the Researcher

Researchers are the principal instrument for gathering and analyzing data (Merriam & Tisdell, 2016). Stake (1995) noted that a qualitative researcher plays various roles, but the role of data collector and interpreter is fundamental because knowledge is constructed, not found. In addition to serving as an interviewer responsible for collecting and interpreting data in this study, I developed procedures for recruiting participants and was the primary instrument for data analysis. Being the sole researcher presented a potential for biases that may have impacted the study. These biases were identified and monitored. I was thorough in collecting and analyzing data to ensure the trustworthiness of this study. The researcher's ethical stance is also significant to the trustworthiness of the study. Maxwell (2013) agreed that ethical concerns should be an integral part of qualitative research. To that end, informed consent was obtained, and the confidentiality of selected participants was protected. Most importantly, I was aided by the Institutional Review Board (IRB) guidelines established for qualitative research.

My role as the sole researcher included collecting and analyzing data from two high schools in the Southeastern region of the United States. Embracing the various responsibilities to fulfill as the primary researcher required that I reflected on my viewpoints about ELLs, inquiry-based biology instruction, and simulations while conducting this study. I have been employed as a science teacher at the secondary level in the Southeastern region of the United States for 15 years, ten of those as a biology teacher. The first five years of my teaching career, I worked mostly with ELLs. I observed that these students not only struggled with the English language, but they also encountered several barriers, such as limited exposure to science content and access to quality resources to build their biology conceptual understanding. I have mentored novice science teachers for two years in my current position. Teachers have shared with me that they have used inquiry-based teaching and computerized simulations. They have also voiced their frustrations with teaching ELLs and the lack of available resources to help them meet the needs of these students. However, based on my personal experiences as a teacher as well as on anecdotal evidence gleaned from conversations with other teachers, I believe teachers need additional assistance in understanding and implementing inquiry-based instruction when simulations are used in biology. Also, it is my belief that more instructional resources and training are needed to support and improve teachers' instructional practice and technological application with all students—including ELLs in science education. Being aware of these biases, I improved my interactions with teachers and made better decisions as a researcher.

To maintain trustworthiness of the study, my role as a researcher remained separate from my role as a teacher. Since I currently work as a biology teacher in the school district, I did not select participants at my current high school. Also, I had no supervisory role over any of the participants. Although I have mentored other teachers, none of the participants were mentored by me. In addition, participants were informed of their rights to voluntarily participate or withdraw from the study at any time. Informed consent and confidentiality have been protected and strict protocols were followed throughout the data collection and analysis. Pseudonyms were used, and documents collected have been stored in locked cabinets. Electronic files have been password protected. These rigorous methods helped both to protect and enhance the quality of this qualitative study.

Methodology

In the methodology section, a thorough description of the research study is provided. Included in this section are the participant selection logic andinstrumentation; as well as the procedures for recruitment, participation, and data collection. Each of the components mentioned are described in more detail later in the section so that other researchers can replicate this study.

Participant Selection Logic

Participants for this study were selected from two secondary schools in the Southeastern region of the United States. The two sites were selected for their implementation of inquiry-based instruction in relation to simulations. Also, these two sites have high populations of ELLs. I recruited participants from the two research sites using the strategy of purposeful sampling. I was able to select participants who were knowledgeable about inquiry-based instruction and simulations. According to Patton (2015), purposeful sampling allows researchers to align the case selection with the purpose of the study, central questions, and the data being collected. This study had a total of four teachers from the two sites. Two teachers from each site were selected to help gather a saturated amount of data using three data sources to allow this research to answer the research question on how they support ELL students when using biology simulations to promote inquiry learning. Purposeful sampling is aligned with the case selection of two schools, the intent of the study, research question, and the selection of participants to gather in-depth data for the most effective use of limited resources in this study. Henderson-Rosser and Sauers (2017) conducted a case study using a sample of three teachers with pre-and post-interviews on inquiry-based learning using the EQUIP model. Though the number of participants was smaller than what was selected in this study, the researchers obtained an adequate sample for this study. Malterud, Siersma, and Guassora (2015) coined a model called information power. The concept of information power specifies that the more value the sample holds and its significance to the actual study will determine how many participants are needed. They claimed that adequate or satisfactory information hinges on five elements: the quality of the sample, the goal of the research, use of grounded theory, analysis strategy, and quality of discourse. Matlterud et al. (2016) agreed with the idea that sample size in qualitative research is intended for saturation, but saturation is specific to methodology. The information power model is designed to guide novice researchers in obtaining adequate sample size for qualitative studies. Merriam and Tisdell (2016) agreed that in qualitative research "the crucial factor is not the number of respondents but the potential of each person to contribute to the development of insight and understanding of the phenomenon" (Merriam & Tisdell, 2016, p.127). This multiple case study contained a sample of four individuals from two schools who have implemented inquiry learning and online simulations in their classroom. These individuals possessed the knowledge to contribute their insights to understanding the phenomenon. The logic that undergirded the purposeful sampling strategy was that in a qualitative design study, a smaller sample affords the researcher the opportunity to collect "information-rich cases" for in-depth study (Patton, 2015, p. 265). Obtaining the richest data possible from participants in this case study provided in-depth understanding of the phenomenon of ELLs using online biology simulations in the classroom in relation to biology teachers' instructional support to promote inquiry-based learning. Also, information was collected from interview, simulations, and lesson document sources; therefore, four participants from two research sites were adequate as a sample size for this multiple case study.

After receiving the signed letter of cooperation from the principals of each research site, I sent emails to potential participants who met the following inclusion criteria: (a) Must be certified in biology, (b) have two or more years of teaching high school biology courses, (c) taught high school biology to ELLs, (d) have implemented inquiry-based instruction, and (e) have implemented online biology simulations. I sought approval to conduct the study in the school district. After the head of the program identified these teachers and submitted their information to me, I emailed a copy of the demographic questionnaire for them to complete before selection. I selected potential participants from the two research sites based on these criteria with the assumption that they possess knowledge and experience with the phenomenon being researched; they also completed the demographic questionnaire and responded with "I consent" to the informed consent form.

Instrumentation

The following data collection instruments were used in this multiple case study: (a) interview protocol (b) Scaffolding Resource Data Collection Form (c) EQUIP Simulation Data Collection Form, and (d) Simulation + Scaffolding Resource Document Data Collection Form. I developed these tools based on the research of Merriam and Tisdell (2016), Stake (1995), and Miles et al. (2014). Table 2 contains the alignment of the instruments to the research questions I used to collect data at the two research sites. The interview protocol has been aligned with the conceptual framework, the central research question, and the component questions and related subquestions. Also, the EQUIP Simulation Data Collection Form (Appendix B) is aligned with related sub-question 2.2, while the Scaffolding Resource Data Collection Form (Appendix C) is aligned with related sub-question question 2.2 and interview question 2. The Simulation + Scaffolding Resource Document Data Collection (Appendix D) was used to help compare and contrast data between simulation online and simulation + scaffolding related to the student experience and answer related sub-question 2.3.

Table 2

Alignment of the Data Sources to Component Questions and Related Subquestions

Data sources	RQ1	RSQ 2.1	RSQ 2.2	RSQ 2.3
Interviews	✓	✓	✓	
Scaffolding resource data collection form			✓	✓
EQUIP simulation data collection form				✓
Simulation + scaffolding resource document data collection form				✓

Interview protocol. According to Stake (1995), interviews are the primary mode of data collection to understanding multiple realities. Interviews are done with the intent of having participants providing descriptions or explanations of an event (Stake, 1995). Unfocused interviews yield too much unneeded information, and "an overload of data will compromise the efficiency and power of the analysis" (Miles et al., 2014, p. 39). The interview protocol for this study was based on Merriam and Tisdell (2016) recommendations on conducting effective qualitative research interviews. According to Merriam and Tisdell, interviews permit a researcher to gain understanding on a phenomenon from participants, which is not readily observed. In this study, the semi-structured interviews allowed me to obtain detailed and practical information on teacher's use of biology simulations to promote inquiry learning with ELL students. Following recommendations from Stake (1995), Merriam and Tisdell (2016), and Miles et al. (2014)

on creating interview questions that elicit extended responses, I developed these open-ended interview questions, which aligned with conceptual framework and the research questions in Table 3.

Table 3

Alignment of the Interview Protocol with Conceptual Framework and Component Questions and Related Subquestions

Interview questions	Conceptual framework	CRQ	RQ1	RQ2	SQ2.1	SQ2.2
1. Describe the strengths and challenges you have observed in how ELL students handle simulation inquiry learning.	EQUIP	✓	✓			
2. In relation to using your selected simulation, describe any instruction, resources, class activities, assignment modifications, or supplemental handouts you provided for ELL students to support their simulation experience.	EQUIP & ZPD	✓		✓	✓	
3. Describe how the use of online simulations in the laboratory support ELL students' understanding of scientific inquiry.	EQUIP &TUSI	✓				✓

These interview questions are constructed to engage participants in an information-rich dialogue regarding their support of ELL students when using biology simulations to promote inquiry learning. However, before the formal interviews began, I introduced myself and stated the purpose of the study and its benefits to biology teachers.

I asked participants if they had any questions for me to continue the participant-researcher relationship building process. Also, I reminded them that their information shared will be kept confidential. Furthermore, I informed them that the interview will take 20-30 minutes of their time to gather extensive descriptive information that would help in understanding the phenomenon being studied from their responses of the interview questions. I developed open-ended and probing questions as part of the interview protocol. According to Merriam and Tisdell (2016), fewer and more open-ended questions are better to allow the researcher to listen and probe for substantive information about the phenomenon. Appendix A contains the interview and probing questions I used to focus on teachers' experiences of inquiry-based learning with ELLs when they use online simulations, and I asked these probing questions from the participants to garner a better understanding of their experiences as recommended by Merriam and Tisdell (2016).

Online simulation. To collect data on samples of online simulations that participants have used with ELLs, I designed the EQUIP Simulation Data Collection Form, which is aligned with the element of the EQUIP model. I used this form to collect data in determining the qualities of inquiry of the biology simulation the teachers have used with ELL students. The EQUIP Simulation Data Collection Form in Appendix B offered five factors with distinct indicators, which helped answer research sub-question 2.3 on the level of inquiry biology simulations address for ELL students. I wrote detailed notes of each indicator for the level of inquiry with the EQUIP independently; I then summarized the overall inquiry level for the indicator. For example, instruction contains instructional strategies, order of instruction, teacher role, student role, and knowledge acquisition. Looking at instructional strategies within the simulation, textual and detailed notes were written for the indicator. The overall instruction level of inquiry was indicated for instruction. The same process was repeated for each indicator using the online simulation. Evidence from the simulation was analyzed later using coding and categorization.

Lesson document. To collect data on lesson plans, lesson documents, and modifications handouts, I created the Scaffolding Resource Data Collection Form in Appendix C and the Simulation + Scaffolding Resource Document Data Collection Form in Appendix D. Documents are often collected in case study research to corroborate what individuals stated in interviews, and "augment evidence from other sources" (Yin, 2014, p. 103). Yin also noted that documents may also contain contradictory information, for they are written with intended purpose and audience other than those of case studies. For this study, I collected three types of documents. I requested a copy of the handout that students will use to complete their assigned simulations, a copy of the teachers' lesson plan document, and a copy of any modifications they use with ELL students. These documents either provided detailed verification of what teachers said in their interviews or contained contradictory information. The Scaffolding Resource Data Collection was used to collect data to answer research question 2 and sub-question 2.2 and four of the following indicators of the EQUIP model: instruction, discourse, curriculum and assessment. Textual information was noted for each indicator. Based on the evidence gathered from the documents, the level of inquiry and the overall inquiry level will be noted in Appendix C. Simulation + Scaffolding Resource Document Data Collection Form was used to gather information pertaining to research question 2 and 2.2. I used this form to gather textual information from the modification documents. See Appendix D. This form was used to evaluate any differences between the level of inquiry from the simulation online and simulation + scaffolding related to the student experience with the modifications.

Procedures for Recruitment, Participation, and Data Collection

Participants for this case study were recruited from two research sites. The participants were chosen based on the following inclusion criteria: that they taught biology, used the inquiry-based approach, had ELLs students, and used online simulations. Likewise, the two research sites selected for this study have implemented online biology simulations with their ELLs students. I used multiple sources to gather data from mentioned locations. This section included the descriptions of how I recruited participants and how they participated in this case study. Also, it contained the data sources I used to collect information leading towards answering the central, component and related subquestions for this case study.

Regarding procedures for recruitment, I contacted the superintendent of the school district. In researching school districts that use online simulations in the explorelearning.com website, I found three school districts that have used simulations. I sent an email to all three school districts research and evaluation directors. However, I selected the district that is closest to my work location. In the letter, I explained the purpose of the study and requested a signed letter of cooperation signifying willingness to join the research study. In addition, I communicated with principals at each research site, explaining the purpose of the study and the criteria established for participating and asking for signed letters of cooperation. The letter outlined my need to conduct interviews with participants.   According to Jacob and Furgerson (2012), a quiet and semi-private room should be chosen to minimize background noise and obtain quality recording of the interview. Participants had a choice on the location of their interviews. However, I did request for a quiet area to maintain privacy and to avoid distractions from supervisory officials at the schools from principals, chairpersons, or students. After obtaining teachers' names from the principals based on the inclusion criteria, I looked up individual email address using the school district public directory, sending emails to potential participants within the district at both research sites to invite them to participate in the study.

Regarding the participation process, once email addresses for biology teachers were obtained, I sent emails to participants who responded affirmatively. A copy of the informed consent form and Part I of the interview protocol was attached to the email. The body of the email included a brief introduction to the study with the informed consent attachment requesting them to respond with the words "I consent" via email if they were willing to participate in the study. Once the teachers returned their signed consent forms, I contacted them to explain the individual interviews and collect lesson documents process. Also, I followed up with a phone call to schedule dates and time for 30 to 45-minute interviews as well as to request lesson documents and information regarding specific online simulations being used. Any participant who met the inclusion criteria but was not selected was notified that I planned to keep them in the pool of qualified teachers in case one of my active participants decided to withdraw from the study.

Concerning data collection, I gathered data from multiple sources in this case study. Multiple sources included interviews, documents, and online simulations in relation to inquiry learning with English language learners. The data collection process for the multiple sources is explained below.

Interviews were one data collection technique used in this study to help me answer the component questions and related subquestions 2.1 and 2.2. Participants received a copy of the interview protocol a week before interviews. The day before the interview, I sent an email to participants confirming the interview time and place. I visited each research site prior to the scheduled interview dates, and on the day in question, I arrived 15 minutes before the scheduled time and ensured that both the voice recorder on the android phone and the tape recorder are operable and the location was quiet and void of distraction. I asked if participants have any questions about the interview protocol sent to them via email, reminded them that they could withdraw from the study at any time, and confirmed the time frame of 20 to 30 minutes with participant prior to starting each interview. Also, I reminded each participant that the interview will be recorded and that probing questions may be asked to draw a deeper understanding of the experience shared. At the end of each interview, I thanked the participants for their time and their willingness to join the study. I reminded participants that I planned to share a copy of the transcript as a form of member-checking to ensure that I transcribed what they had stated, and they could be contacted for follow-up questions. I ended the interviews by asking the participants if they have any questions and left my email address in case any questions arose later.

The second data collection technique was to examine the online simulation used by each participant. Teachers were asked to provide the URL of the online simulation they will use with their students in Part 2 of the demographic questionnaire before the interview, which will be requested after receiving their informed consent. Upon receipt of the simulation URL, I filled out the top half of the EQUIP Simulation Data Collection Form in Appendix B, including the date, time, name of the online simulation, URL, purpose of the simulation, and the content of the simulation. The rest of the form discussed the five indicators of EQUIP model—time usage, discourse, instruction, curriculum, and assessment—I completed in detail when the simulation was reviewed in its entirety. This instrument helped me gauge the levels of inquiry that were evident in the online biology simulations that the participants were using and provided data to help answer research sub-question 3.1.

In addition to interviews and online simulations as data sources, the third data collection source was lesson documents. Documents can support and strengthen evidence from other sources (Yin, 2014); therefore, for this study, I asked teachers to send their lesson plans, lesson documents, and supplemental handouts that correlate to the simulations the students used as an attachment via email. I asked teachers to provide these documents before the interviews. Obtaining these documents ahead of the interviews allowed me to understand the concepts taught and to help me probe the participants during the interviews. After collecting these resources from the teachers, the Scaffolding Resource Data Collection Form was used to assess the level of inquiry within the documents used with the simulations. The Simulation + Scaffolding Data Collection form helped to determine if and how the inquiry levels are modified from the original intent of the online simulation by any pre, during, or after teaching or support the teacher may have provided to the students. While the Scaffolding Resource Data Collection Form helped to answer related r sub-question 2.1, the Simulation + Scaffolding Data Collection form allowed me to gather information to answer both related question 2 and sub-question 2.1 and determine if the level of inquiry differs when teachers used modification strategies to support ELL students with biology simulations.

Data Analysis Plan

As the sole researcher for this multiple case study, I was responsible for collecting, managing, transcribing and analyzing the data. According to Merriam and Tisdell (2016), the goal of data analysis is to find answers to derived research questions, which are the categories or themes. I used manual coding and Word from Microsoft Office, which was well-suited for the three data sources, interviews, online simulations, and lesson documents. Interviews were transcribed from audio-recorded to a word document by using Google doc speech to text. I checked the transcription accuracy by listening to the recording while reading the word document before sharing it with the participants for member checking. Textual data were recorded as I reviewed each simulation with the EQUIP Simulation Data Collection Form. Each indicator was assessed individually using the EQUIP inquiry level; then the overall inquiry level was noted for that indicator. The same process was followed for the lesson documents using the Scaffolding Resource Document Data Collection Form. I followed the two-cycle data coding process that Miles et al. (2014) recommended for qualitative research to code the interviews, simulations, and lesson documents.

The first cycle of coding is called chunking, in which segments within the data were identified and labeled from “single word to a full paragraph to an entire page” (Miles et al., 2014, p. 72). Using this first cycle allows researchers to detect repeating patterns that could be developed into categories. This cycle was used to analyze the interviews, simulations, and documents separately for each case using coding and categorization. Using this approach as part of the data analysis, I developed codes based on the conceptual framework and used the line-by-line coding as recommended by Charmaz (2015). In analyzing each line of the transcribed interviews, I also used the descriptive, *in vivo* coding methods to assign “labels to data to summarize in a word or short phrase” (Miles et al., 2014, p. 74). However, these codes are derived from the participant’s own language and are used as codes. The same process was used for the textual evidence from the simulations and documents. I used the textual information from the simulations and documents to categorize phrases, concepts, and themes. See Appendix E for the codebook and F for the themes. I conducted a content analysis using the Simulation + Scaffolding Data Collection Form. Miles et al. (2014) recommend *in vivo* for beginning qualitative researchers learning to code data. As a novice qualitative researcher, I used the *in vivo* as a coding approach to ensure that concepts remain close to the participants’ words and to capture key descriptions of how teachers support ELL students using online biology simulations in the classroom; however, these codes were placed in quotation marks to differentiate them from those I derived as Saldana (2016) suggested. The first cycle coding analysis continued with axial coding in which common themes and patterns will be condensed and categorized. Merriam and Tisdell (2016) described the first cycle as within-case analysis, in which each case was analyzed separately. The same process was followed as I reviewed the data from interviews, simulations, and documents at each research site.

Data analysis continued with the second cycle as Miles et al. recommended. In the second cycle, also known as pattern coding, summaries were grouped into smaller categories or themes. This approach is "cluster-analytic and factor-analytic" to allow research to condense voluminous amount of data into analytic units; in relation to multiple case study, "it lays the groundwork for cross-case analysis by surfacing common themes and directional processes" (Miles et al., 2014, p. 86). Saldana (2016) agreed that the second cycle involves the development of an organized "metasynthesis of the data corpus" and attributed meaning to that organization (p. 234). This study involved two cases; therefore, the same codes and categories were developed for all the data sources of each individual case. These codes were merged into single codes or categories to help determine themes and discrepancies. Merriam and Tisdell (2016) noted that the second part, which is the cross-case analysis, can offer an "integrated framework covering multiple cases" (p.234). Miles et al. (2014) and Yin (2014) noted that cross-case analysis augment the transferability and generalizability of case study findings. Like repeating experiments in quantitative studies, cross-case analysis allows replication; and attention is drawn to emergent themes to compare or contrast data from multiple sources. Several researchers support the multiple case study design because it increases data variation, allows replication, and strengthens validity. Yin (2014) noted that replication strategy could be used to determine the applicability of themes. Because this study involved the multiple case design, I conducted a cross-case analysis across all sources of data for both cases to determine themes and discrepant data. These themes were analyzed in relation to the research questions and be interpreted according to the constructivism perspective, the EQUIP model, the TUSI model, and the literature review for this study.

Evidence of Trustworthiness

Ensuring trustworthiness of a study involved ensuring validity and reliability through conducting research in an ethical manner. According to Merriam and Tisdell (2016), validity and reliability must be approached through careful attention because they offer evidence of the rigor of a study and augment the usefulness of the findings. Meriam and Tisdell (2014) and Yin (2014) acknowledged the significance of trustworthiness in a qualitative study. In this study, trustworthiness was discussed in relation to credibility, transferability, dependability, and confirmability. Each component was described in relation to the strategies I used to enhance the trustworthiness of this research study.

Credibility

Patton (2015) discussed four distinct elements concerning the credibility of qualitative inquiry: (a) “systematic, in-depth fieldwork that yields high-quality data,” (b) judgments or “systematic and conscientious analysis,” (c) the researcher’s training and experience of the qualitative research process, and (d) the "philosophical belief in the value" of the qualitative research process (p. 653). While Merriam and Tisdell (2016) added that credibility involves congruency between the findings of a research study and reality based on the presentation of the data. Credibility of the study examines whether the findings make sense to the participants and readers and whether the researcher presents an accurate picture of the phenomenon explored (Miles et al., 2014). These researchers provided specific strategies to improve credibility in qualitative research. Merriam and Tisdell offered the following strategies related to credibility: triangulation through cross-checking data, respondent validation, adequate engagement in data collection, searching for discrepant data, and peer examination.

Concerning triangulation, both Patton (2015) and Merriam and Tisdell (2016) agreed that it improves the credibility in qualitative research. I used the triangulation strategy to address credibility in this study. First, I used it to facilitate validation of the data through cross-checking three data sources, interviews, online simulations, and documents for convergence. Also, I used this strategy to compare emergent themes from interviews data to those of online simulations and lesson documents from both research sites. Furthermore, I also used the strategy to analyze common themes from the three sources for divergent or discrepant themes. Merriam and Tisdell (2016) noted that some writers posit the purposeful search of that data that might "disconfirm or challenge your expectations or emerging findings" (p. 249). Moreover, I used the strategy of respondent validation by asking participants to review the findings, ensuring meanings attributed to their experiences were not misinterpreted. These strategies were used to ensure credibility of the study.

Transferability

According to Merriam and Tisdell (2016), transferability is synonymous to external validity. They defined transferability as the extent to which the findings are applicable in other situations. Also, the authors recommend using several strategies to using transferability, such as providing rich, thick description and maximum variation in the sample. In this study, transferability involved the use of rich and thick description in relation to the data collection and the data analysis process. Providing detail and concrete descriptions about data collection and data analysis of the study allowed replicability. Additionally, the cross-case analysis of emergent, divergent, or discrepant data helped establish transferability. Participants were selected from two sites within the Southeastern of the United States. Similar standards are covered in biology within the United States, though the simulations used to teach the standards may differ. Also, ELL students were similar concerning the English language; however, they possess different levels of English proficiencies. Providing detailed descriptions of the data collection, data analysis, and the participants in the two cases were examined to ensure transferability of the study.

Dependability

Dependability, which Merriam and Tisdell (2016) referred to as reliability or consistency, is “the extent to which research findings can be replicated” (p. 250). They also warned that because reliability is difficult to achieve because of the dynamicity of human behavior, consistency of results with data collected is significant in addressing the reliability of qualitative research. Triangulation, researcher's position, member-checking, and the audit trails are strategies recommended to ensure dependability. Data were triangulated by comparing teacher's responses to interview questions and the documents provided for analysis. Regarding the researcher's position, I did not select participants that worked at my current school, and I followed the interview protocol closely to refrain from asking participants leading questions; I also kept a journal of my thoughts throughout the data collection and interpretation process. After transcribing the interviews, I shared the transcripts with the participants for any discrepancies between the transcribed copies and what was stated as a form of member-checking. To improve reliability of this study, I included the instruments used to collect data, and I maintained detailed records of the data analysis process. As described in the previous section, data were triangulated by comparing multiple data sources and cross-case analysis of emergent, divergent, and discrepant data.

Confirmability

Merriam and Tisdell (2016) presented the term objectivity in place of confirmability. Concerning confirmability, Patton (2015) noted the role a researcher's philosophical belief plays in the qualitative research. Recognizing how the researcher's values and preconceptions could affect every part of the study, Patton suggested using an audit trail to corroborate the rigor of confirmability of gathered data to reduce bias, enhance accuracy, and present impartial findings. Merriam and Tisdell (2016) concurred that the researcher's biases must be clarified so that the reader can arrive at a clear understanding of the interpretation of the data. Though I am a biology teacher who taught ELL students, my role as a researcher was to gather information help answer the developed research questions of this study without soliciting responses from participants. Participants were asked the interview and probing questions in the interview protocol. Also, I kept a journal to record my own feelings throughout the data collection and interpretation process of this study. I used the audit trail by taking copious notes throughout the data collection and analysis process, as described in the previous section to maintain objectivity of the study.

Ethical Procedures

Ensuring an ethical study required that I safeguard trustworthiness to strengthen the credibility and reliability. Also, I followed the IRB guidelines for conducting research involving participants. I applied to the IRB at Walden University to conduct the study and received the approval number 11-03-17-0380297 for the study. Data collection could not start until IRB approved my application. I used the IRB directives and the recommendations for conducting qualitative research in an ethical manner from Merriam and Tisdell (2016).

Concerning participants, Merriam and Tisdell (2016) noted that the main area of ethical concern is the relationship between the researcher and the participant. To maintain this relationship and ensure that none of the data were overheard, I secured the participant's chosen location by requesting that it was not accessible to any supervisors, teachers, or students during the time of the interviews. Likewise, any documents obtained were marked with an identifier only known to me rather than the names of the participants. Furthermore, electronic conversations and documents were password protected. Merriam and Tisdell (2016) offered three ways that the researcher-participant relation can influence the collection of data and data presentation of the study: (a) transparency in presenting the purpose of the study, (b) clarity in offering appropriate informed consent, and (c) simplicity in explaining privacy and protection from harm. Researchers need to address the elements as part of the study.

To ensure transparency, I included the purpose of the study in the informed consent form that participants received and signed before obtaining their information. Also, as mentioned as part of the data collection, I reviewed the information with each participant before each interview session. I reminded participants of the interview protocol in relation to the purpose of the study. They were informed that the interview session will be between 30 to 45 minutes, and that I would record their responses and probe for more in-depth understanding of their experiences. Participants were given time to seek clarifications or ask any questions pertaining to the purpose of the study and its potential outcomes.

The informed consent form contained the procedures for participating in the study. Participants responded with “I consent” to this form affirming their willingness to participate in the study. Included in the form was the understanding that participants could change their minds and withdraw from the study at any time. Also included were the procedures established to ensure confidentiality and protect participants’ privacy by requesting a private area void of distractions. Participants knew the risks and benefits involved. This study involved minimal risk; for example, participants may have found interview questions a bit challenging to answer. Concerning compensation, it was noted in the consent form that participants would receive a gift card to show my gratitude, which did not bind them to continue participating in the study.

Summary

Chapter 3 included a description of the research method for this study. I explained the research design and rationale, the role of the researcher, the methodology, and issues of trustworthiness and ethical procedures. Participants were purposefully selected based on inclusion criteria from two research sites to elicit responses on the central research question. I provided a description of the data collection instruments, the data collection plan, and the data analysis plan. In addition, I described strategies to enhance the trustworthiness of the study as well as the potential ethical issues are discussed. Findings from this multiple case study will be discussed in Chapter 4.

Chapter 4: Results

The purpose of this qualitative multiple-case study was to explore how biology teachers support ELLs when using biology simulations to promote inquiry learning in biology within a school district in the southeastern region of the United States. To achieve this purpose, I studied how teachers support ELLs when using biology simulations to foster inquiry skills, which also included how they perceived ELL students' strengths and weakness, and the levels of inquiry evident in the biology simulations. I did this at each research site by interviewing teacher participants, analyzing the online simulation used with students, and analyzing the teacher lesson plans for when they implemented the simulation with students.

The central research question for this multiple case study was as follows: How do biology teachers support ELL students when using online biology simulations to promote inquiry learning?

The component questions and their related subquestions were as follows:

1. How do teachers perceive ELL students' strengths and weaknesses in relation to inquiry learning using simulations?
2. How does teacher scaffolding influence the level of inquiry for ELL students?
    - 2.1. How do teachers describe their scaffolding to support ELL students' inquiry learning during the implementation of biology simulations?
    - 2.2. How do teachers use scaffolding in online simulations to make scientific inquiry understandable to ELL students?

2.3. What level of inquiry do teachers address in biology simulations for ELL students based on the indicators of the EQUIP framework?

This chapter contains the results of this multiple case study. It includes a description of the setting of the two research sites where I conducted this study. The participants from the two high schools who partook in this study had used biology simulations with ELL students. Participant demographics are also presented, which include the courses that participants taught during the school year, other content areas they have taught in previous academic years, how long they had been teaching, if they have taught ELL students, how they define inquiry learning, and if they currently have ELL students in their classes. Furthermore, data collection procedures are described, with more details about data analysis procedures about how interviews were conducted and scaffolding documents were gathered. The data analysis process is also presented with a single case analysis that entailed the coding and categorizing of each data source and the cross-case analysis for all data sources. Moreover, the cross-case analysis of the categorized data of all the data sources was completed to determine emergent themes and discrepant data of the two cases. In addition, evidence of the trustworthiness of this qualitative study and the strategies that were used to improve the credibility, transferability, dependability, and conformability of this study are explained. Finally, the key results of the study are analyzed and described in relation to the central, component questions and related subquestions.

Setting

This study was conducted in two high schools within two public school districts. Site A was Grassy Lake High School (pseudonym), which is in the Longwood school district (pseudonym) and Site B was Timberwolf High School (pseudonym), located in the Marsh View school district (pseudonym). Both sites were high schools located in the Southeastern region of the United States. These sites were selected because they have a high population of ELLs students and offer biology courses. These sites were also chosen because they have biology teachers who used simulations with ELL students.

Site A, located in the Longwood school district, had a total enrollment of 193,000 students in Pre-K through 12th grades during the 2017–2018 academic year, with over 60% of the students considered as being economically disadvantaged. A total of 24,946 students were considered as ELLs, which corresponded to 12.9% of the district overall student population. According to the U.S. Census (2012), 34.4% of all County residents speak languages other than English at home, and 24.1 % of children under the age of 18 are living in poverty. The diversity within the county was affirmed by the 146 languages and dialects spoken, which embodied 191 countries and territories in the world. Also, the demographics indicated a racial/ethnic composition of 29% Hispanic, 28% Black, 36% White, and 7% other. Longwood High showed similar racial and ethnic diversity as the district. It had an enrollment of 3,010 students from Grades 9 to 12 during the 2017-2018 academic year. The student body was made up of 52% male and 48% female, and the total minority enrollment was 61%. The number of ELL students enrolled at the school fluctuated throughout the year from 169 to 73 based on the Gold Report in education. All students at this high school are required to take three science classes before graduation; biology is included as one of the three courses. The same biology course is offered at all the high schools in the district. A student could decide to take biology during their ninth grade year or in 10th grade. Regardless of their grade level, they are required to be assessed annually with an end of course (EOC) examination. In 2016-2017, about 676 students took the biology EOC, and 66% of them achieved a Level 3 score, which was counted as showing proficiency. However, 27% ELL students obtained a Level 3 or higher. Compared to 2016-2017, a total of 709 students took the biology EOC, and 72% attained proficiency. In 2018, Grassy Lake tested 842 students, and 73% achieved a Level 3 or higher; the data had not been disaggregated at the time I conducted the study.

Site B, located in the Marsh View school district, contained a population of 271,517 students. A total of 34,065 students were considered as ELLs, which corresponded to 12.5% of the district overall student population. Marsh View demographics showed a racial/ethnic distribution of 51.3% White, 3.8% Asian, 40.3% Black, 0.8% Native American or Native Alaskan, 0.2% Native Hawaiian or Pacific Islander, and 3.7% Multiracial. Marsh View serves a diverse student population of students from 204 different countries who speak 191 different languages. Timberwolf High reflects the same diversity as the district, with a population of 240 ELLs from its 2,380 students, and with a racial demographics of 49% Black/African American, 23% Hispanic, 22% White, 3% Asian, and 3% multiracial. It has the second highest high school ELL population in the district. Similarly to Grassy Lake High School in Longwood, all students have to take three science classes before completing high school, and of them has to be biology. Also, of the 628 students who took the biology assessment, 48% demonstrated proficiency by obtaining a developmental score of 395 or Level 3. In 2016-2017, a total of 653 were assessed, and 57% scored a Level 3 or higher; however 16% of the ELL students achieved a Level 3 or higher. This year, Timberwolf high tested 561 students, and 48% achieved a Level 3 or higher, but the data had not been disaggregated at the time I conducted the study.

Both research sites followed the same scope and sequence in covering the various concepts in biology. Teachers from both sites also used online simulations and implemented an inquiry-based learning approach. The sites also had different racial/ethnic students taking biology. Each had a higher number of ELL students attending their schools. However, Timberwolf High School had a smaller overall student population in comparison to Longwood High School, which might have influenced the difference in proficiency performance levels in 2016-2017. The 2018 scores had not been disaggregated for both research sites at the time the study was conducted.

Participant Demographics

Participants were selected at two research sites because they reported that they had ELL students, used simulations, and the inquiry learning approach, and taught biology classes. This information is detailed in Table 4. Pseudonyms were used to protect the privacy of the participants.

Table 4

Demographics for all Participants in the Study

Participant	Licensure	District/ high school	Years teaching	Subject areas taught	Use simulations/and had ELLs
Jeannie	Biology	Longwood/ Grassy Lake High	4	Biology & Env. Science	Yes
Stewart	Biology	Longwood/ Grassy Lake High	4	Env. Mgmt & Biology	Yes
Dianne	Biology	Marsh View/ Timberwolf High	3	Biology & Env. Science	Yes
Marlene	Biology & Earth/ Space	Marsh View/ Timberwolf High	14	Biology/ Biology 1 ESOL	Yes

Note. Abbreviations: Env. means environment or environmental and Mgmt stands for Management.

At each site, two teachers participated in the study. Each teacher had to provide their teaching information on Part I of the interview protocol. The specific demographics of the participants involved in the study were outlined, which included subject taught and years of experience in teaching, as denoted in Table 4.

Site A, which is Grassy Lake High School in the Longwood school district, had two biology teachers who have taught other content areas. They have been employed at the school district for 4 years. The two participants have also taught ELLs students and have used simulations in the past 9 months. Though they defined inquiry learning differently, they professed to have used the inquiry learning approach in their classroom.

Jeannie (pseudonym), a biology and environmental science teacher at Grassy Lake High School, had 4 years of teaching experience with ELLs students. She defined inquiry learning as giving the students the opportunity to show what they know. She only taught biology the first 3 years of her teaching career. She was given an additional subject area in 2017. She also taught environmental science to ELL students. She taught at another high school where they had more ELL students. Jeannie has been at this school for only a year. She has used several simulations and virtual labs. She shared the Gizmos simulation on flower pollination, which she also mentioned in her interview.

Stewart (pseudonym), also an environmental management teacher at Grassy Lake High School, taught science there for 4 years. He taught biology for 2 of the 4 years at the school. Stewart admitted that he used to have more ELL students when he taught biology. He defined inquiry learning as “allowing the students to solve problems and answer questions on their own with teaching serving as a guide at best rather than a director.” At the time of the study, both Jeannie and Stewart used simulations to support ELL students with their understanding of biology concepts. He used a simulation on photosynthesis.

Similarly, at the second site, Timberwolf High School in the Marsh View school district, the two participants used simulations and the inquiry learning approach with ELL students. However, one participant had 14 years of teaching experience, compared with the participants in the Longwood school district. Both participants noted that the inquiry learning approach is student-centered and teacher-facilitated. Also, both participants have been at the school for their entire teaching career and taught ELL biology at the time of the study.

Dianne (pseudonym), one of the ELL biology teachers at Timberwolf High School, had three years of teaching experience. She taught biology, environmental science, and anatomy and physiology. Her description of inquiry learning entailed a student-centered process where the teacher facilitated learning by asking students higher order open-ended questions and providing them with opportunities to critical think. She has used several simulations with ELL students, such as ELLevation and Gizmos. She utilized the frog dissection, which she referred to in her lesson plan

Marlene (pseudonym) was the other ELL biology teacher at Timberwolf High School. She has been teaching for 14 years. She completed her master's degree in educational leadership this year. Aside from ELL biology, she also taught physical science, Earth science, life science and environmental science. She was the teacher with the most teaching experience of all the participants. Compared to Dianne, Marlene's definition of the inquiry learning approach included teacher facilitating student-centered activity to support learning. Both Dianne and Marlene submitted one lesson and utilized the same simulation, which was the frog dissection. They both referred to it during their interviews.

As I sought to complete this study, my intended goal was to invite biology teachers who met the inclusion criteria, which included teachers who are certified in biology, had two or more years of teaching high school biology courses, taught high school biology to ELLs, have implemented inquiry-based instruction, and have implemented online biology simulations. At both sites, I found teachers who satisfied these inclusion criteria. All selected participants were biology teachers with teaching experiences that ranged from 3 to 14 years. In addition to teaching biology, all the teachers taught other science courses within their school district. A summary of the demographics of the participants is presented in Table 4. All the participants ascribed their meaning to the term inquiry learning.

Data Collection

For this qualitative multiple case study, I gathered data from three sources. The first data source was the interviews. I interviewed four biology teachers that taught English language learners (ELLs), used the inquiry learning approach, and utilized online simulations or virtual labs. The second data source was from the online simulations or virtual labs that teachers used with their students. The third data source included lesson plans, and scaffolding documents used in conjunction with the simulations. Also, to ensure trustworthiness and ethical standards of this qualitative research, I followed strict data collection and analysis procedures. In this section, I describe the data collection and analysis procedures.

Interview Data

After obtaining the informed consent from the first participant on January 26, 2018, I replied with a thank you email and attached a copy of Part 1, 2, and the interview protocol. The respondent sent back Part1 two days later. However, I did not receive any additional informed consent responses from that same location for three months. On May 15, 2018, another participant responded with an “I consent” email. I sent a thank you email with the Part 1, 2, and the interview protocol attached. In addition, I sent a follow up email to the first respondent to return Part 1 and 2. From the other research site, I received the informed consent from both participants on May 22, 2018 and May 23, 2018. Both received an email the same day with Part 1 and 2 attached. I received Part 1 and 2, and two lesson plans from three respondents on May 25 and May 29. The fourth participants sent his lesson plan after his interview on June 11, 2018.

I obtained most of the scaffolding documents prior to coordinating the interviews with the participants. All the teachers agreed to participate in the interview at a time convenient for them. Two participants agreed to be interviewed in their classroom. However, I requested that their interviews be conducted during non-instructional time without distraction from administrators and students. The other two respondents decided to be interviewed via telephone. I reminded them that they will need a quiet area because the interview would be taped. Interviewed were scheduled on the same day for the teachers who wanted to be interviewed in their classroom, and the other interviews were conducted over the phone a few days later. A summary of interview data collection is found in Table 5 below.

Table 5

Interview Data Collection

Participants	High school	Interview medium	Date	Length of interview
Jeannie	Grassy Lake	Face-to-Face	05/31/2018	26:55
Stewart	Grassy Lake	Face-to-Face	05/31/2018	42:35
Dianne	Timberwolf	Phone	06/08/2018	41:45
Marlene	Timberwolf	Phone	06/04/2018	28:15

At Grassy Lake high school in the Longwood district, I conducted two in-person interviews. I arrived at the school at 12:15 to meet the first respondent, who was the only individual in the room. I greeted and thanked Jeannie for taking the time to participate in the study. I reminded her that the interview would be taped, and it would last about 20-30 minutes. The first interview started at 12:20 and ended around 12:47. It took about 10 minutes to walk to the other participant's classroom. Stewart greeted and welcomed me into his classroom. I thanked him for his participation and reviewed the procedures for the study. Also, I reminded him about the purpose of the research, the duration of the interview, and asked if he had any questions for me. My second interview was conducted for 42 minutes and 35 seconds.

Two additional interviews were conducted at Timberwolf high school in the Marsh View district. These participants agreed to be interviewed over the phone. I called Marlene on June 4, 2018 at 3:30 to conduct the interview. I asked her if she had a chance to review the interview questions, but she had not and said I could continue and everything would be fine. My interview with Marlene ended 28 minutes and 15 seconds later. On June 8, 2018 at 4:10, I interviewed Dianne for 41 minutes and 45 seconds. I followed the interview protocol (Appendix A) for each interview. To ensure accurate transcription, I used the laptop and the phone to audio record all the interviews. Minimal field notes were written during the interview for I needed to focus on the participants' responses to ask follow-up questions. After each interview, I transcribed as much of the interview as possible using Google Doc. dictate. All four interviews were conducted within eight days and transcribed within four days.

Simulation Data

Teachers received Part 1 and 2 of the interview protocol after consenting to the research study. Part 1 provided demographic information while Part 2 contained information about simulation. Teachers were asked to return Part 2 along with their lesson plan, the name of the simulation, and the URL. Also, they provided their definition of inquiry-based learning. All the participants returned the requested information, which is summarized on Table 6. Two participants provided simulations about flower pollination and photosynthesis. The other two participants worked collaboratively and submitted one simulation on frog dissection. I printed copies of the scaffolding documents that came with the simulation directly from the websites the teachers provided to compare to the copies they sent to me via email.

Table 6

Simulation Used by Each Participant

Participant	High school	Simulation title	Simulation URL
Jeannie	Grassy Lake	Flower pollination	www.explorelearning.com
Stewart	Grassy Lake	Photosynthesis lab	http://www.glencoe.com
		Photo lab	http://www.kscience.co.uk
Dianne	Timberwolf	Frog dissection	http://www.glencoe.com
Marlene	Timberwolf	Frog dissection	http://www.glencoe.com

Document Data

I sent Part 2 of the interview protocol after receiving the email from participants that they consented to the research study. Participants had about two to three weeks to send the scaffolding documents and lesson plans to me via email. Three of the four participants send the scaffolding documents before the interview except for Stewart. I received his lesson plan on June 8, 2018, a week after the interview. Documents I collected included teachers' lesson plans, and scaffolding documents used in conjunction with the simulation.

Data Analysis

For data analysis, I used an inductive approach. Miles et al (2014) stated that the inductive approach involves the discovery of repeated phenomena that are associated and contain patterns (p. 238). Using the two-cycle coding process as recommended by Saldaña (2013), I conducted open coding for each data source in first cycle, followed by the second cycle coding to identify themes. Then I conducted a cross-analysis for themes for the two cases.

Initially, the data analysis process started with transcribing all four interviews. The transcription process allowed me to remain close to the data and force my attention on each statement from the respondents to recognize repeated statements. I reviewed the recording to twice as I read through the transcribed interviews to ensure accuracy. Using two primary tools, Word documents with tables to organize the responses from the participants and the codes, and Excel workbooks to help tag salient statements. I read each phrase or sentence twice to gain a clearer understanding of the response from the participant, then I used different colors to indicate words, phrases, or concepts that are repeated from the transcript. Then I noted any concept that described the meaning of the text to help me identify possible emergent themes in the margins. In the first cycle, I coded the data using a mixture of coding methods, which included open or emergent coding process. Also, included was *in vivo* coding, where I used participant's exact words for the codes (Saldaña, 2013, p. 4). I interviewed teachers of ELL students who shared their experiences, so in vivo coding allowed me to capture their experience. Furthermore, I used process coding to develop code words to show actions teachers use to support their ELL students (p. 96). Saldaña claims these three methods of coding work well together for first cycle coding (p. 96). The iteration of the first cycle required close comparison for similarities and differences of the interviews and renaming codes. I revised the codebook to reflect the iterative process of coding. At the end of the first cycle of coding I had 28 codes. These initial codes can be found in Appendix E.

Next, I used content analysis to examine the online simulations, scaffolding documents, and lesson plans. The content analysis started with reading through the simulation all the way through once. Then I went back and performed each step of the simulation like a student would have experienced it, without using Appendix B: EQUIP Simulation Data Collection Form. Then, the third time, I used Appendix B and assigned a score to each inquiry element in the simulation. Each element received a score following the Marshall et al. (2009) EQUIP protocol, a score 1 meaning the element is at the preinquiry level, 2-developing, 3-proficient, and 4-exemplary. I utilized the same approach with the Scaffolding Resource Data Collection Form to analyze the scaffolding documents and lesson plans. See Appendix C. I added all the scores of the inquiry elements and divided by 4, which provided its average inquiry score. Also, I added the overall scores of the indicator for each simulation, scaffolding document and lesson plan and divided them by the 4 indicators to get the mean inquiry level across the simulation, scaffolding documents, and lesson for each case. Finally, I calculated the mean of each simulation, scaffolding documents, and lesson plan for the case. In addition to using the EQUIP, I also did perform content analysis of the simulations and in conjunction scaffolding documents for the use of technology in science instruction, the unique features of technology to support inquiry learning, and how technology make scientific views more accessible. Summaries of all the data sources are included in the results section.

In the second cycle coding, I used axial coding to create themes that address the research questions by grouping the codes I acquired from the first cycle. According to Miles et al. (2014), the second cycle requires grouping summaries into smaller constructs or themes or "subsuming particulars into general" (p. 285). Patterns emerged from the first cycle based on each data source, which included interviews, online simulations, scaffolding documents, and lesson plans I coded and the content analysis conducted. Codes were then clustered into categories. Miles et al. (2014) noted that creating categories allow researchers to organize the vast array of data into groups. During the second cycle coding, collected data were compared within and across cases to determined emergent themes related to the research questions and the literature review. Although variations existed with the categories, patterns emerged from each data source resulting into the five themes. I organized the findings based on the five themes and aligned them to the research questions. The process of thematic analysis involved the "enumerative induction" with constant comparison within and between the two cases (Miles et al., 2014, p. 292). Such analysis requires the researcher to demonstrate inductive reasoning and be broad-minded to recognize the "conceptual overview landscape" of the coded data (p. 292). Sperry (2010) added that the inductive reasoning process entails the synthesis of parts to one unifying concept or theme linking the incongruent data into a comprehensive explanation.

I analyzed data across all data sources to establish the within-case and cross-case themes. Determining the within-case themes required the analysis of each data source within each individual case. Miles et al. (2014) suggested using this approach to help explain what has happened in a single case or school (p. 100). Through constant comparative analysis of the within themes, I continued with the cross-case themes and determined discrepancies within and between the two cases. Performing a cross-case analysis has helped deepen the understanding and explanation of the key findings in this multiple case study.

Evidence of Trustworthiness

Ensuring trustworthiness in qualitative is significant as it involves upholding validity and reliability through conducting research in an ethical manner. Merriam and Tisdell (2016) acknowledged that both validity and reliability must be approached through careful attention because they provide evidence of the rigor of a study and supplement the usefulness of the findings. Credibility, transferability, transferability and confirmability are the four components that contribute to the rigor of this research study. Each construct is described in relation to the strategies I used to enhance the trustworthiness of this study.

Credibility

Merriam and Tisdell (2016) claimed that credibility involves congruency between the findings of a research study and reality based on the presentation of the data. Credibility of the study examines whether the findings make sense to the participants and readers and whether the researcher presents an accurate picture of the phenomenon explored (Miles et al., 2014). Merriam and Tisdell also offered several strategies related to credibility, for example triangulation through cross-checking data. Data triangulation was conducted by comparing and contrasting the findings that emerged from the interviews, online simulations, scaffolding documents, and lesson plans. Also, I used the member checking strategy by asking participants to review the transcripts for accuracy of their responses to the interview questions and the findings ensuring meanings attributed to their experiences were not misinterpreted. These strategies were used to ensure credibility of the study.

Transferability

Transferability is synonymous to external validity (Merriam & Tisdell, 2016). It is defined as the extent to which the findings are applicable in other situations. Merriam and Tisdell recommended using rich, thick description and maximum variation in the sample to ensure transferability. In this study, transferability involved the use of rich and thick description in relation to the data collection and the data analysis process. I provided thorough description about the settings, participants, and how the data were analyzed to allow replicability. Participants were selected from two sites within the Southeastern of the United States. Similar standards are covered in biology within the United States, though the simulations used to teach the standards differed. Also, ELL students were similar concerning the English language; however, they possessed different levels of English proficiencies. Providing detailed descriptions of the data collection, data analysis, and the participants in the two cases were examined to ensure transferability of the study. Additionally, the cross-case analysis of emergent, divergent, or discrepant data were conducted as Yin (2014) suggested to strengthen transferability of the findings.

Dependability

Merriam and Tisdell (2016) referred to dependability as reliability or consistency. Also, they warned that because reliability is difficult to achieve for the dynamicity of human behavior, consistency of results with data collected is significant in addressing the reliability of qualitative research. Triangulation, researcher's position, member-checking, and the audit trails are strategies recommended to ensure dependability. Data were triangulated by comparing and contrasting teacher's responses to interview questions and the scaffolding documents provided for analysis. Cross-case analysis of emergent, divergent, or discrepant data were conducted to ensure dependability. Regarding the researcher's position, I did not select participants that worked at my current school, and I followed the interview protocol closely. Also, after transcribing the interviews, I shared the transcripts with the participants for any discrepancies between the transcribed copies and what was stated as a form of member-checking. To improve reliability of this study, I included the instruments used to collect data, and I maintained detailed records of the data analysis process.

Confirmability

Concerning confirmability, Patton (2015) noted the role a researcher's philosophical belief plays in the qualitative research. Recognizing how the researcher's values and preconceptions could affect every part of the study, Patton suggested using an audit trail to corroborate the rigor of confirmability of gathered data to reduce bias, enhance accuracy, and present impartial findings. Merriam and Tisdell (2016) concurred that the researcher's biases must be clarified so that the reader can arrive at a clear understanding of the interpretation of the data. As I was the sole researcher that collected, managed, and analyzed the data in this study, the interview protocol was followed closely to prevent soliciting responses from participants. Also, I recorded my own feelings throughout the data collection and interpretation process of this study. I used the audit trail by writing notes throughout the data collection and analysis to maintain objectivity of the study.

Results

At the end of data analysis, I had five themes that I aligned to the research questions. See Appendix F. The five themes were: teacher awareness, ELL students' abilities and barriers, instructional assistance, and pedagogical approaches, and virtual lab implementation. Figure 2 shows the five themes that emerged from the inductive coded data to categories during the second cycle coding: ELL students' abilities and barriers, Teacher awareness, Instructional Assistance (a) Accommodations, (b) Pre-instruction, (c) During instruction, (d) Post instruction, Pedagogical approaches, and Virtual lab implementation.

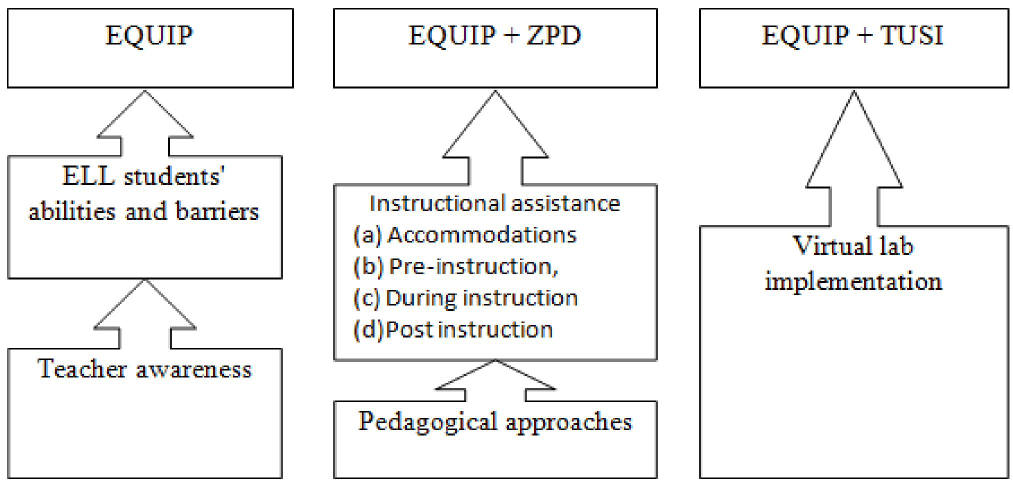

Figure 2. Five emergent themes based on the conceptual framework of the study.

The following paragraphs contain the synthesis of the emergent themes and the vignettes from the data to support the themes. Each participant shared their experience and perceptions of ELL students' abilities and barriers, support strategies used with ELL students, use of simulations and the unique features of technology with ELL students in their classrooms. The results of the study are organized based on within-case analysis for each theme and the cross-case analysis of the two cases.

Emergent Themes

Examining the answers from the participants revealed their perceptions of simulations in using them with ELL students. They described the benefits and the drawbacks of these simulations. The coded data showed their cognizance of the lack of resources available in the classroom. The first two themes correspond to research question 1, related to teacher awareness and ELL students' abilities and barriers.

Component Question 1

Research question 1: How do teachers perceive ELL students' strengths and weaknesses in relation to inquiry learning using simulations?

The first theme related to this research question was *teacher awareness*. Pertaining to teacher awareness, the participants perceived several benefits and drawbacks to inquiry learning using simulations with ELL students. From Case 1, Jeannie noted that simulations are user-friendly, and she would prefer to use them instead starting her lesson by providing students with the live specimen. Referring to the flower pollination simulation she used with her students, she assumed that giving them a live specimen flower, the students would not have understood the pollination process. However, she claimed to only have four to five computers in her classroom. Furthermore, she acknowledged that some students view the simulation as games "the simulation means playing a video game." She emphasized, "That's good and well, but I need them to know what we're talking about and how it works." Though the students view the simulation as a video game, Jeannie emphasized her role as an educator by employing technology to support her students understanding of the process of self-pollination and cross-pollination in flowers.

On the other hand, Stewart perceived that simulations are easier to modify than hands-on labs. He shared, "Like the photosynthesis simulation on the computer, you know like the carbon could be from the atmosphere or it may be from some other source. You can modify the type of color." However, he acknowledged that students will continue their labs seeking to get the same results as their teacher if the hands-on lab is modeled for them, especially ELL students. He claimed,

> With the real lab, you get result of course, if you do it correctly, but you get expected results. That is, here is the problem, in general, even with regular kids but ELL kids too. Like if f you are doing a lab, and I model it and I'm showing like okay this is my dependent variable and so this is why I expect to see, and this is what I'm measuring. Well that the students are going to do it until they get that.

Also, he noted that simulations provide immediate and unpredictable results, but they lack reality and the results are limited and concrete. He added, “You are limited by what has been programmed into the simulation and so the things that are not programming in the simulation are not going to be in it, but they may exist in reality.” He also noted that he only has four to five computers and no bilingual dictionaries in his classroom. Both participants shared that they did not have enough computers in their classroom.

In Case 2, both Dianne and Marlene remarked that simulations are powerful for ELL students. Marlene said, “It gives them a chance to the visuals,” regarding the frog dissection she used with her ELL students. However, she also perceived that simulations with various steps would hinder ELL students’ conceptual understanding:

> If the lab tends to be too complicated with many parts, then you may end up losing them in the process because they get overwhelmed. The lab does not do what you intended it to do. Let's say for example, you were doing something with enzymes or a complicated inquiry process, for something like that it might be easier to break it down like the scientific method or something that you may think

that this lab might be great to do for a Virtual Lab but depending on how many steps they have to do it may not be very beneficial to them.

While Dianne observed assigning ELL students simulations as homework would also impede their content learning. She declared, "I did notice even though I gave them 3 trials, and I pick their highest score, a couple of them did good, but majority of them did not do good." She perceived the hindrance arose from ELL students' lacking technological skills. All four participants shared their experiences on the benefits of using simulations with ELL students but also acknowledged the negative features of simulations.

The next theme related to RQ 1 was ELL students' abilities and barriers. Both participants from Case 1 recognized that ELL students have abilities and barriers when using simulations. They could recognize visuals, have prior knowledge, but they lack conceptual learning due to limited content explore. They also struggle with the English language. According to Jeannie, ELL students can manipulate the simulations because they feel that they are part of the program. Jeannie noted that simulation prompted the students "to think ok what's my function what is this part and what is the next step instead of me giving them a piece of paper which they don't want to read." She added that simulations are more interactive. Also, they are hands-on and more inviting. She said, "It's more hands-on and it's more interactive." She continued, "The kids are more geared towards doing that, and they're doing it themselves they're getting instructions on how to do it." Jeannie noted that ELL students view the simulation as a game, which makes it more inviting for them to show their strengths by what they already know about the concept. Using simulation, “Students have the opportunity to reveal what they know or do not know about a specific topic” said Jeannie. She acknowledged that simulations allow ELL students to demonstrate their prior knowledge, especially with the visualization component with the program. Jeannie commented, “Well! The visuals, they knew the visuals on one flower.” However, she also recognized that ELL students have language barriers and struggle with reading. Pertaining to the flower pollination simulation, she professed “Just the reading part of it. My students were the lower-level language ones not the higher-level.” According to Jeannie, the students needed translation to gain comprehension. In addition, she stated,

“ELL students, some of them were not even exposed to some things versus the regular students.” They also lack conceptual knowledge not related to language barrier but content exposure. She continued “Some of them didn't understand when I said reproductive. They thought it was just male and female in humans not in plants.” ELL students have gaps in their conceptual understanding, where get stumped with content vocabulary words within the simulation.

While Stewart, the other participant noted, “They [ELL students] don’t have to be able to understand the language, the words, the letters, and the pictures they can understand.” Also, they can manipulate the visuals in the simulation easily. Sharing an example from the photosynthesis lab, Steward said, “Like you see how much oxygen it’s outputting at certain period of time, the photosynthesis rate and then again that is something they can manipulate more easily.” He also declared that ELL students have background of common things. Recollecting a specific Spanish speaking student, Stewart said, “So, her background knowledge of basic things like the cat and the tree. That's pretty strong because those are common things even in her country.” He acknowledged that ELL students struggle with reading and the English language “with the simulation as they advance through it, eventually they going to reach a level where they're not going to be able, where the visual cues are not going to be enough so it's not enough to understand. In completing their simulation, Stewart stated that they would need to read to proceed when the visual cues are depleted. In addition, they are also lacking conceptual knowledge because of the limited exposure to the content.

From Case 2, Dianne and Marlene also noted that ELL students could interact and manipulate the simulation program. While only Dianne noted that they do well with the visuals from the simulation because “they feel more confident.” She shared her observation of a student completing a simulation, and she said, “she looks comfortable doing it and she's having fun she's engaged she seems to be a lot more engaged when she is the stimulation.” However, they both noted that ELL students have trepidation about their accent, which hinders their participation in the classroom. Dianne said, “They're afraid to speak up to participate because they may feel they have an accent.” Marlene agreed and declared “they tend to or are afraid to talk because especially if they are ELL in a mainstream class, they concern about their accent.” Also, ELL students struggle with reading.

Teachers also shared about various barriers for ELL students doing simulations. One barrier shared was related to student’s previous experiences using technology. Dianne noticed,

> Some of them, they may not be able to manipulate the simulation, depending on their levels, their countries that they're from or their economic status. They may not have a computer available or they're not used to a computer or how to use it so sometimes I may have to assist them with some basic ways of like managing or controlling the computer so sometimes there is an issue.

ELL students struggle with reading and technological skills, "When had if they read the directions they could have known oh you just put the cursor on it you hold and drag it over and what not." She continued "So they often would ask me oh Ms. Dianne, how do I drag this from this to there." Also, Dianne emphasized that all her students tend not read directions not just ELL Students. She also noticed that they lack conceptual understanding and have language barriers. She noted, "It's a lot easier for them to understand English, but it's a lot harder for them to write and speak it. So, I notice sometimes they're not able to communicate." Furthermore, ELL students struggle with content vocabulary. Her students showed understanding of the concept when manipulating the visuals, but "it's the vocabulary that's hindering them because I can clearly see that they understood the process or the task at hand." Regarding one of her students, she added,

> She was struggling with the vocabulary, but she still tried to participate and when she did the activity and tried to communicate it, someone would say oh she doesn't even understand or what not, but when she's doing the simulation you can see she understand it.

Altogether, Dianne recognized that ELL students could manipulate simulations because they contain visuals, and students feel confident and comfortable working on their own though they lack the language to fully read and understand the concepts. She observed them showing their understanding while going through the process. They are afraid to participate because of their accent; they lack conceptual knowledge and content vocabulary.

In addition to the language barrier, Marlene noted that ELL students can vary greatly in their ability to communicate in English. She emphasized that ELL students have different subgroups, therefore they have different struggles. She noted that “They have varying needs within their subgroups, where you have some of them that are gifted where they have taken some these courses in their native language in their own countries.” She also supposed that some of them struggle because this information is new to them and never learn using the inquiry process. Furthermore, she stated “ELLs are not created equal just like any other groups of kids.” She shared that during a lesson,

> I may have half of the class gets it but still have a portion struggling no matter what I do, because the leap is still very difficult for them. Maybe some them they didn't go to school.

She shared that they have “gaps in their learning”, and their accent prevent them from participating in class especially in mainstream classes where they do not want to be viewed differently.

All four participants shared that ELL students could manipulate simulations. Also, they all agreed that ELL students struggle with reading. However, three of the four participants noticed that ELL students do well with the visualization incorporated within the simulations, but they lack conceptual understanding. Also, all four teachers described that ELL students have gaps in their learning, and struggle with both English language and reading.

Component Question 2

Research question 2: How does teacher scaffolding influence the level of inquiry for ELL students with each indicator of the EQUIP framework?

The three themes that correspond to RQ2 were *instructional assistance, pedagogical approaches,* and *virtual lab implementation*. Also, results utilizing the EQUIP from the simulations, scaffolding documents used in conjunction with the simulations, and lesson plans were utilized to answer the questions. Moreover, the simulations provided valuable information from the content analysis of the simulations and in conjunction scaffolding documents for the use of technology in science instruction, the unique features of technology to support inquiry learning, and how technology make scientific views more accessible. Holistically, all three data sources aided in answer research question 2.

RQ 2.1. Data from teacher interviews were used to answer RQ 2.1 How do teachers describe their scaffolding to support ELL students' inquiry learning during the implementation of biology simulations? The two themes related to 2.1 were *instructional assistance* and *pedagogical approaches*. The first theme of *instructional assistance* had four sub themes of (a) accommodations, (b) pre-instruction, (c) during instruction, (d) post instruction.

Regarding accommodations, all participants from both cases noted that they provided students with accommodations during the inquiry learning process to help them reach their ZPD. In Case 1, Jeannie reads to the ELL students. She noted that many of her students are low level English readers, so she would read the instructions with them as they manipulate the simulation. On the hand, Stewart used the fluent English speakers in his class to assist the students with low English language skills when necessary. He said,

> If I really need the help, then I'll try to find another student that speaks Spanish in particular. I have in one of my class, I have these two girls that always sit together; one is pretty fluent in English. They're both ELL but one is at a higher level than the other and so if there is an issue I can try maybe have her explain it better after I had explained it to both.

Also, he shared that ELL students need additional time to complete their assignments, so this is another type of accommodation he makes for these students. He said, "It takes them a bit longer." His lesson plan on photosynthesis noted that ELL students received 50-100% additional time to complete their work. He recollected a particular scenario that involved providing the student additional time to connect with the learning personally "it involves them going home and trying to connect with it personally." He emphasized that he does not rush them, and they have plenty of time to get their assignments in.

Another accommodation is allowing access to additional materials or resources. The participants from Case 2 allowed their students to use dictionary.com and Google translate during simulations. In the scaffolding documents, Dianne and Marlene instructed their students to use a specific website to look for unfamiliar vocabulary words. See Appendix G. Dianne also noted that she would let them to use their phones to translate specific key terms during the simulation activity. However, they are not allowed to use their phones during lectures. Marlene shared,

> I may have to put the caption on if it's a let's view a YouTube video or something else a simulation where sometimes you don't put the caption on and slow it down or pausing a lot more than I would have to do because they are trying to translate some of the stuff in their own language.

In addition, Marlene noted that she would try to support her students by requesting that they get tested for reading proficiency. Based on their performance, she would suggest that they work with a paraprofessional one-on-one.

Data from lesson plans corroborated that teachers use pre-instruction strategies with ELL students. Jeannie and Stewart used visuals and pre-reading materials to prepare their ELL students for their lessons. Jeannie provided her students with charts, graphs, diagrams, and video clips. For example, in the data analysis of the lesson and the scaffolding documents, for the flower pollination Jeannie noted visual aids and video clips from Brainpop and Discover Education. A copy of the flower she provided to her students before the simulation is found in Appendix K as part of the scaffolding documents she used with the live flower dissection. She asked them probing questions to activate their prior knowledge. Also, she added using the vocabulary with cognates to support her ELL students. Her lesson plan showed a list of the vocabulary words she provided to the students, which match the structures of the flower. She noted that the students would need to drag and match those structures to their function in the simulation. However, Stewart used brainstorming activities, prompting questions, and root words. He declared that many of the biology vocabulary words have Latin and Greek roots. For example, “Some of those words are big, like photosynthesis. I mean I don't speak Spanish. I tried to break the words down.” Both participants also take advantage of the visuals from the simulations to help their ELL students understand the overall concept with their lesson and achieve their ZPD.

In addition to diagrams and pictures, Dianne reported using the KWL chart to activate her students’ prior knowledge. She said,

> So, I have for the pre-at first, I do like a KWL chart to see where they stand with the human body system because the main reason we do the frog dissection is to compare the anatomy of the frog versus the human being because the body systems are somewhat similar, so I do a KWL chart with them.

Analysis of the lesson plan showed students received five minutes to work on their KWL chart. Dianne used additional pre-instruction techniques such as sharing samples of assignments from the previous year students to show her current students the expectations. She also used science foldables prior to simulations. Marlene’s pre-instruction included using a short video clip before her instruction. Analysis of the lesson plan showed that she instructed the students to watch a 5-minute video clip of a living frog, then they participated in a think-pair-share activity regarding how the frog’s behaviors are similar to human behaviors, such movement, breathing, eating, and reproducing. Marlene also shared that she provided students with vocabulary words for the lesson and ask them to draw pictures of them, so they have the visuals. Her lesson plan showed that she used laminated English/Spanish vocabulary words. Furthermore, she would use the word sort activity to help them connect the vocabulary to the overall concept being taught. She remarked,

> You are introducing these words, some of them have never seen before, so word sort gives them an opportunity to play with the word even if it's for 15 minutes, and maybe do something hands-On with the word and have a discussion with their partners. Vocabulary word is used in context instead of being taught in isolation.

Moreover, Marlene stressed the significance of the visuals in the simulations to activate ELL students' prior knowledge. She noted "I think it makes easier, but I can't say this enough, the visual component." The scaffolding documents on the frog contained diagrams of the frog students had to label. Also, the lesson plans contained diagrams, such as the Venn diagrams students used to compare and contrast frog and human's anatomy. All four participants underscored the importance of visuals with ELL students.

Sub-theme (c) during instruction involved teachers using supportive strategies such as motivation and thinking skills to improve conceptual understanding. Jeannie noted that she provided her students with the extra push they need to complete their assignments in the form of motivation. Also, she acknowledged that the extra guidance is needed to help them perform deeper analysis. The scaffolding documents on Flower pollination she provided contained several examples of analysis questions. Stewart agreed and noted that additional guidance is necessary when the students do not understand the main concept of the lesson. He would take time to explain the lesson again. Teachers also monitor their students' learning by using proximity and walking around the classroom. Jeannie said, "I would continue going around room and I would actually have them help each other before I give my help." Analysis of the lesson plan on flower pollination showed that she used a pair-up buddy system in her class during discussions. Stewart professed to use the same during instruction strategy, saying he would "go from table to table." However, he was using this approach to ensure that the students remained on task. If they are not task and they are still not getting the lesson, then he said, "I of course sit at the table and I try to guide them face to face at that point, because anyone that's having trouble, particularly ELL students." During instruction, Jeannie also shared that she acts as a facilitator. While Stewart disclosed that he chunked the concepts. He would say, "We'll just do one thing at a time you know find me one thing that relates this concept and explain to me how it affects your everyday life." One of his strategies was helping ELL students to make connections to real world situations.

Dianne and Marlene from Case 2 used supporting strategies in the form repetition. Dianne provided the students with additional websites to locate the information they need. Both participants noted that students could repeat the simulation in order to gain understanding of the concept. Dianne said, "if they don't understand something they can go and repeat." Marlene added "whether it is a video or a virtual lab, they can do it over and over and if they don't get it like the first time or they don't understand, and since it's online, they can refresh it." Marlene accentuated her point about repetition by stating,

> So, I think this is really the beauty for language acquisition, because repetition is what we need enough to acquire the language not just you know the day to day basic English, but the academic language for them to hear it over and over again, so I think the visual and repetition, not just learning the English.

ELL students can acquire the BICS and the CALP through repeating simulations. Also, she noted that she provides additional support by chunking the concept to help her students become independent learners. Both participants monitor their students' learning. Dianne walks around assist ELL students. Also, she used a learning scale for the students to show their progress, the lesson plan on the frog mentioned the learning scale as an assessment tool. She declared,

> I have a learning scale in my class so in their notebook they must write from 1 to 4, 1 meaning they don't understand anything, 2 they're ok but they need a lot of help, 3 means they're good they got it, and then 4 means they not only get but they can actually teach it to a classmate. So, they must write on the top of their paper and while doing the activity I go around they have to show me what number they are.

Marlene also monitors her students by using checklist with all her requirements. She would walk around the room with a clipboard reinforcing positive behaviors. Furthermore, she exclaimed that during instruction, she provided students with analysis, review, and self-check questions. Analysis of both the scaffolding documents and lesson plan on the frog simulation showed that she used analysis questions. Moreover, she would ask students to revise their responses while completing the simulations.

The last sub-theme (d) focused on post instruction. All four participants used content assessment as post instruction. Jeannie used exit tickets with questions on structure and function of plants' organs to assessment her ELL student. Stewart assigned his students research projects where they draw the process of photosynthesis and cellular respiration their own illustrations and answer questions. Also, he wanted them to show the reactants and products of the two processes. He remarked, "These research projects that involve combination of answering these questions and drawing the concepts that has been very successful." Analysis of the lesson plan on photosynthesis reflected that students work on group projects on photosynthesis and cellular respiration where they had to identify reactants and products of the two processes. Also, he used remediation when students do not achieve a passing score on their projects.

Dianne and Marlene assessed students' learning with quizzes and post lab questions. Dianne shared that she asked post lab questions to test their understanding about the dissection lab. Analysis of the scaffolding documents and lesson plan on the frog simulation revealed that they assessed students daily exit tickets and post-lab questions. Similar to Stewart, Dianne also assigned research projects to her students. They would present their finding to the class. However, she emphasized the importance of feedback. She said,

> I did give them two type of feedback. First feedback is as a class at the end of the presentation. I ask the whole class what did you guys like about so and so presentation and then they say it and the next question what they could do to improve to make it better.

She provided individual feedback to her students, stressing that she shared the good part with them first followed by areas they needed to improve. Marlene also used post lab questions, which her students had ahead of time. She added, “They were asked specific questions that if they paid attention and do their lab properly they should be able to answer.” For example, data analysis of Marlene’s supporting scaffolding documents on the frog scaffolding documents, confirmed that students had to answer several multiple choice, short response, and extended response questions after the lab. See Appendix J. They work with a partner to answer the questions based on the simulation and the whole lab. All participants utilized varied instructional support, such as accommodations, pre-instruction, during instruction, and post instruction to scaffold their instruction and assist their ELL students in achieving their ZPD.

The second theme related to related subquestion 2.1 was *pedagogical approaches.* Teachers reported sharing strategies and attending workshops or professional learning communities (PLCs). Three of the four participants noted that had learned a specific strategy during interactions with colleagues. However, all four of them used different teaching practices to support their ELL students. They differentiated their instruction by using teacher-led inquiry, collaborative learning, independent learning using simulations, and hand-on experiences.

Jeannie from Case 1 had students work in pairs, used teacher-led inquiry by providing them with scenarios, questions, or specific problems to solve. She continued the teacher-led inquiry with questions checking students’ understanding about the expected outcomes. However, analysis of her lesson plan showed no evidence of students receiving scenarios and specific problems to solve. Also, she noted that during independent learning, she is “non-existent” as the students know what to do. She reverts to being the classroom facilitator. She added that during independent learning, students used simulations, which allowed them to manipulate everything, rather than having her come around and constantly guiding them to complete a task. She said, “I did not want them to be totally dependent on me or my notes.” This shows that she wanted her students to reach their ZPD.

Another pedagogical approach is collaborative learning. Stewart grouped his students based on cognitive and English proficiency levels. He stated that he modeled the hands-on lab for his students, “I showed exactly what they need to do.” Based on the EQUIP, the scaffolding documents he used with simulation showed a higher inquiry level at developing. However, modeling the lab by showing the student exactly what they needed to accomplish would be considered preinquiry. Stewart used other pedagogical approaches such as differentiating his instruction with lectures, using simulations, providing hands-on lab experiences, and assigning research projects. However, he acknowledged that he had to modify his narrative prompts for the ELL students. He said,

> I'm trying different things. I tried the narrative things, but it doesn't work as well with ELLs. I've tried having students go home to their own community and find example of how photosynthesis has affected her in one case it was I think pollution affected her life.

Rather, he would allow the students to work on alternative research projects that would require them to illustrate the concept of photosynthesis. He added that he started this new approach to help the ELL student focus on key concepts. Also, asking students to illustrate the concepts through illustration would demonstrate their understanding.

To differentiate her instruction, Dianne from Case 2 shared that she taught the same concept in different ways:

> I do it in three different ways. The first one is a paper cutout that they do the paper cutout of the frog dissection. And then the second one I do, is the virtual frog dissection. And then the last one is the actual real hands on frog dissecting.

In addition, she differentiated her instruction through PowerPoint Notes, simulations, and hands-on labs. Also, she paired up and grouped her students for collaborative activities based on English fluency "I try to pair them up or another student who is better with the language system." In addition, she noted at times, she grouped the students based on their prior knowledge from the KWL activity. Though the lesson plan noted that both Dianne and Marlene used the KWL activity, it did not mention using the responses from the students for collaborative learning purposes.

Marlene, the other participants from Case 2, shared that she differentiates her lessons by asking students to complete foldable of the frog body parts prior to completing the simulation. For the frog dissection, students also have 3D paper model prior to live dissection. She also emphasized that modifications are needed, especially when students are being assessed. She stated that many times the ELL students are complying without understanding, which incites the needs to modify her lesson. However, the lesson plan and the scaffolding documents provided on the frog dissection did not have any evidence of modifications implemented with this lesson. During collaborative learning, Marlene utilized various approaches to group her students. She would group them based on similar languages in sheltered classes. However, she admitted, "getting them to work on the language skills or the language acquisition in addition to the content can be difficult because they go to their comfort zone." Rather she would group them "with kids that may not speak their language, where it forces them to go through the inquiry process as well as focus on English." Also, she would incorporate discussion questions for students to answer with their partners that required them to "interact with and deepen their knowledge." The lesson plan contained several activities when students had to interact in in pairs, teams, and groups. For example, as part of the lesson procedures from the frog dissection lesson plan, Marlene wrote,

> Students will think-pair-share 5 minutes on how body shape of the frog is similar to human anatomy. Using computers, students, through Think-aloud discussion will list major organs found in humans and/or frogs 5 minutes. Students will, as a group, discuss and complete a Venn diagram comparing and contrasting the human & frog anatomy.

She added that they loved to collaborate, especially during simulations because sometimes as teachers we teach them too fast. Furthermore, Marlene employed the classroom management system ClassDojo to group students for cooperative learning based on specific expectations such as "appropriate talk"; she assigned a table leader to each group. She claimed that assigning a leader to each group who know the requirements, liberate her to monitor and assist the students who needs more support. Also, it allowed them to take in more responsibility and made them more independent and less dependent on me. She shared that she would give the students points based on predetermined criteria. She said, “I try to make it more positive where they are earning points not necessarily losing points.” She also gave them points for participation.

Though both participants shared their definition of inquiry and mentioned using inquiry, most interview responses did not describe inquiry-based learning approaches. Marlene shared her belief about inquiry learning coupled with the simulations, she said,

> The inquiry process if utilized would have the greatest impact on student achievement for all kids, but especially for ELL students because once they're in the classroom you can directly impact them. If we move more towards the inquiry-based model where simulations are constantly being infused into the classroom, I think student achievement will just happen, by the way of student learning, because it will be authentic and it won't be forced.

Though she believed that inquiry learning when coupled with simulation could have a great impact, the results of the level of inquiry from the EQUIP show a difference between their lesson plans and the scaffolding documents they used in conjunction with the simulation. All the participants used various pedagogical approaches to meet the needs of their ELL students, such as modified instruction, independent research projects, simulations, hands-on lab, and the inquiry learning. However, the results showed discrepancies between interview data and the levels of inquiry from the EQUIP analysis.

Related subquestion 2.2. Scaffolding documents and lesson plans were evaluated using the EQUIP in order to answer related subquestion 2.2. How do teachers use online simulations to make scientific inquiry understandable to ELL students? And interview data were also used to answer related subquestion 2.2. Table 7 and 8 contain the EQUIP results for the scaffolding documents and lesson plans for Case 1 consecutively. The overall mean of the scaffolding documents for Case 1 was proficient. Also, Table 9 and 10 show the EQUIP results for Case 2 with the overall mean of the scaffolding documents at developing and the lesson plan at proficient.

Table 7

Scaffolding Documents: EQUIP Pollination & Photosynthesis Simulation Case 1

Overall inquiry indicators		Flower pollination	Photosyn-thesis	Case 1 overall indicator
Instruction of level of inquiry		Proficient 2.6	Exemplary 3.6	Proficient 3.1
Discourse of level of inquiry		Proficient 2.6	Proficient 3.3	Proficient 2.8
Assessment of level of inquiry		Developing 2.3	Proficient 3.0	Proficient 2.7
Curriculum of level of inquiry		Developing 2.0	Developing 2.3	Developing 2.2
	Mean of each scaffolding document	Developing 2.4	Proficient 3.1	Proficient 2.7

The mean of each scaffolding document is shown in Table 7. It shows the inquiry level for each indicator of the EQUIP framework for the two scaffolding documents in Case 1. The mean of the Flower Pollination was 2.4, developing. However, the Photosynthesis scaffolding documents was rated proficient, so the overall mean for the level of inquiry from the EQUIP framework for Case 1 was proficient.

Table 8

Lesson Plan: EQUIP Pollination & Photosynthesis Simulation Case 1

Overall inquiry indicators	Flower pollination	Photosyn-thesis	Case 1 overall indicator
Instruction of level of inquiry	Proficient 3.0	Developing 2.4	Proficient 2.7
Discourse of level of inquiry	Developing 2.3	Proficient 3.3	Proficient 2.8
Assessment of level of inquiry	Developing 2.3	Exemplary 3.5	Proficient 2.9
Curriculum of level of inquiry	Developing 2.3	Developing 2.3	Developing 2.3
Mean of each lesson plan	Proficient 2.5	Proficient 2.9	Proficient 2.7

Lesson plans analysis for both the flower pollination lab and the photosynthesis from Case 1, overall were rated at the proficient level of inquiry, according to the EQUIP, as shown in Table 8. The flower pollination lesson plan rated developing for 3 of the four inquiry indicators, and proficient for one. The photosynthesis lesson plan scored higher with one exemplary, two developing, and one proficient in the various inquiry indicators. A lower score for a virtual dissection scaffolding documents makes sense as the purpose of the experience was the help students learn anatomy of a frog and compare it to human anatomy, and the simulation was not set in an inquiry scenario. So, the scaffolding documents scored low on the EQUIP. Compared to the photosynthesis lab scaffolding documents, supported students doing a lab that required them to develop a hypothesis and test it by simulating data collection and making conclusions, so it scored a higher level inquiry.

Table 9

Scaffolding Documents: EQUIP Inquiry Levels for Frog Dissection Case 2

Overall inquiry indicators		Frog virtual lab	Case 2 overall indicator
Instruction of level of inquiry		Developing 2.0	Developing 2.0
Discourse of level of inquiry		Developing 2.0	Developing 2.0
Assessment of level of inquiry		Developing 2.0	Developing 2.0
Curriculum of level of inquiry		Developing 2.0	Developing 2.0
	Mean of each simulation	Developing 2.0	Developing 2.0

Tables 9 and 10 have the EQUIP results for Case 2. Table 9 shows the inquiry level for each indicator of the EQUIP framework for the frog simulation scaffolding documents. The mean of the frog simulation was at developing. So, the overall mean for the level of inquiry from the EQUIP framework for Case 2 was developing. Compared to the two simulations used from Case 1, the frog simulation showed a lower level of inquiry at 2.0, while the mean from Case 1 was 2.7.

Table 10

Lesson Plan: EQUIP Inquiry Levels for Frog Dissection Case 2

Overall inquiry indicators		Frog virtual lab	Case 2 overall indicator
Instruction of level of inquiry		Exemplary 3.8	Exemplary 3.8
Discourse of level of inquiry		Proficient 3.0	Proficient 3.0
Assessment of level of inquiry		Proficient 2.8	Proficient 2.8
Curriculum of level of inquiry		Proficient 2.6	Proficient 2.6
	Mean of each simulation	Proficient 3.1	Proficient 3.1

In Case 2, the lesson plan implemented for the frog dissection activity rated proficient in three of the EQUIP levels of inquiry. The only indicator rated exemplary was instruction. Though the lesson plans from both cases were scored proficient. The lesson plan mean from Case 2 was higher (3.1) than Case 1 (2.7) but both at the proficient level of inquiry.

Interview data were also used to help answer related subquestion 2.1. The theme aligned was *virtual lab implementation*. All four participants shared how they utilized simulations in their classroom to make scientific inquiry comprehensible to ELL students. They used simulations as prelab to hands-on laboratory experiences, to enhance background knowledge, clarify difficult concepts and misconceptions, and to build and improve conceptual understanding. They also used them to make knowledge accessible and because of their feasibility.

Two participants, one from each case shared that they used simulations as prelab before the hands-on lab. Jeannie admitted that using simulations as prelab prepare her students to be more efficient with hands-on labs. She added that the simulation provided them with more practice to perform the hands-on lab with live specimens. Marlene assigned her students the simulation as prelab to build their confidence for the live frog dissection. She said, “They feel more confident that they can do this… for example when they had to do the frog lab, where they were like, ‘You are going to give us a real frog?’” She felt that providing students with a virtual experience first, gave students more context, which help improve their confidence of what they will experience when they do the actual dissection of a preserved real frog. Also, she used the simulation to ease the students into the live dissection. She noted that using real, preserved specimen is often scary and overwhelming to the students. “I gave them a simulation of what the real thing was going to be like.” She added. Using the simulation as a prelab, Marlene allowed her students to replicate the frog dissection virtually, which reduced their trepidation with the preserved specimen. Jeannie stated that after using the simulation to help students understand self-pollination and cross-pollination, she asked them follow-up questions, and demonstrate the process with live specimens. The virtual simulation in some cases were not used by teachers to improve student inquiry skills so much, as to scaffold student experiences to reduce anxiety prior to conducting a hands-on lab.

Both Jeannie and Marlene also acknowledged using simulations to improve ELL students' background knowledge. Jeannie shared that simulations improve their background knowledge for hands-on laboratory activities. Marlene added, "simulations really will help give a little bit of background information that they may be lacking." She continued to say, "I think it kind of put them in an even playing field to give them that information either you already know it and just reaffirming what you know." Marlene agreed that simulations allow the ELL students to gain the background knowledge that would even out the learning gap between ELL and mainstream students. In addition, teachers also use simulations to clarify difficult concepts and misconceptions. Jeannie noted that simulations clarify difficult concepts. She felt that seeing self-pollination and cross pollination from the simulation made it more understandable for the students. Both Dianne and Marlene acknowledged that simulations could clarify misconceptions. Marlene said, "Sometimes the kids believe one thing, but it is something completely different." The simulations provided the students with clarification needed to make the concept understandable. Teachers use the virtual simulation experiences as scaffolding for ELL students to improve basic science background knowledge already taught in other ways.

Teachers professed to teach around simulation experiences to build and strengthen scientific conceptual understanding, particularly for ELL students. Stewart asked his students to make connections to real world after completing the simulation on photosynthesis. Dianne from Case 2 also shared that she used the simulation to build understanding, especially when seemed confused about the biological concept being covered. She noted that simulations have the built-in visuals to assist ELL students with understanding the concept, so she would have them complete a virtual activity or simulation independently after pre-instruction. She continued to share that at times though the students complete the hands-on lab it seemed “robotic.” Students might go through the procedures without understanding, but “when they saw it on the simulation for some reason they understand it a lot better.” According to Dianne, these students perform better on their assessments after the simulation. Three of the four participants shared that they used simulations to build conceptual understanding.

Concerning improving conceptual knowledge, Jeannie noted that students are able to see the parts of the flower in the simulation. Also, they really understand how it works. On the other hand, if she just gave them the flower, they would chop it up without really grasping the concept of pollination. The simulation permitted the students to view flower reproduction process happening and connect the plant structure to the function of the flower. It provided them with a more in-depth view of the various parts of the flower that they would not see with a live specimen. Marlene agreed that simulations “deepen their knowledge.” Also, she added, “Sometimes, it takes a simulation or something online and then they're like oh that's what she was talking about.” Marlene admitted at times it takes a simulation to “bring the concept home” for the student. Simulations make the concept understandable to the student. Dianne noticed that ELL students grasp the lessons a lot easier and improve their vocabulary when she used simulations compared to using other teaching approaches. She said, “I give them the simulation; they get a visual of what it is, so they were able to understand.” The visualization in the simulation helped the ELL students to better understand the concept. Therefore, teachers not only scaffold for the biology simulation, but also use the simulation as a scaffold for hands-on lab activities.

Teachers also shared that they used simulations to make knowledge accessible and because of their feasibility. Stewart noted that he used simulations to introduce different concepts in the classroom. However, he used them mostly “to introduce more difficult concepts in the classroom just because of feasibility.” He added for example working with toxin, which is not possible in the physical classroom. On the hand, Marlene use simulation to make knowledge accessible to her students. She remarked, “I think there are times where you want to expose the kids to something, but it is may not be possible because you don't have the resources.” Simulations offer her the opportunity to still teach her students the concept without the availability of these resources. The participants used simulations in various ways within their classrooms to make scientific inquiry understandable to their ELL students.

Related subquestion 2.3. EQUIP was used to evaluate the online simulations in order to answer related subquestion 2.3. What level of inquiry do teachers address in biology simulations for ELL students based on the indicators of the EQUIP framework? The two simulations used in Case 1 yielded different inquiry levels shown in Table 11. The flower pollination was rated proficient while the photosynthesis scored exemplary. So, the overall inquiry level for Case 1 was exemplary. However, Case 2 had one simulation on frog dissection, which was rated developing as shown in Table 12. Compared to Case 1, Case 2 had a lower overall inquiry level.

Table 11

Case 1: Online Simulation Levels of Inquiry in EQUIP

Overall inquiry indicators		Flower pollination	Photosyn-thesis	Case 1 overall indicator
Instruction of level of inquiry		Exemplary 4.0	Exemplary 3.8	Exemplary 3.9
Discourse of level of inquiry		Proficient 3.3	Exemplary 4.0	Exemplary 3.7
Assessment of level of inquiry		Proficient 3.3	Exemplary 3.5	Proficient 3.4
Curriculum of level of inquiry		Proficient 3.0	Proficient 3.0	Proficient 3.0
	Mean of each simulation	Proficient 3.4	Exemplary 3.6	Exemplary 3.5

Table 11 contains the summary of the EQUIP inquiry levels with the mean of the elements within each indicator for the two simulations of Case 1. For example, the indicator instruction contains instructional strategies, order of instruction, teacher role, student role, and knowledge acquisition. Looking at instructional strategies within the simulations in Case 1, I rated the simulation on flower pollination as exemplary at 4.0 because it started with assessing students' prior knowledge and warm up questions followed by exploration of the key concept with thinking and connection questions throughout. This simulation has minimal directions to follow; students were engaged in investigating to arrive at a strong conceptual understanding of the concept. However, the other simulation within Case 1 on photosynthesis was rated proficient at 3.0, where students were engaged in the activities that helped develop conceptual understanding through reading about the concept and following procedures and occasional lecture to complete the simulation. The same approach was used with the other four elements. The overall instruction level of inquiry for the instruction indicator is 3.9, which is at the exemplary level. Table 11 shows the results of the level of inquiry biology simulations address for ELL students with each indicator of the EQUIP framework in. The overall mean for Case 1 was exemplary.

Table 12

Case 2: Online Simulation Levels of Inquiry in EQUIP

Overall inquiry indicators		Frog virtual lab	Case 2 overall indicator
Instruction of level of inquiry		Developing 2.0	Developing 2.0
Discourse of level of inquiry		Preinquiry 1.0	Preinquiry 1.0
Assessment of level of inquiry		Preinquiry 1.3	Preinquiry 1.3
Curriculum of level of inquiry		Proficient 3.0	Proficient 3.0
	Mean of each simulation	Developing 1.8	Developing 1.8

Table 12 contains the summary of the EQUIP inquiry levels with the mean of the elements within each indicator for the simulation of Case 2. The two participants used the same frog dissection virtual lab. The simulation involved students clicking on several visuals where they received explanations for the visuals. For example, analyzing the order of instruction within the overall rating indicator of instruction was at the preinquiry level in the EQUIP, because the students had to click on the icons to view the parts of the frog. By clicking on the visual, students were provided with audio explanations of the function for each organ. So, the concepts were explained to the students, they had minimal opportunities for inquiry, which occurred after receiving explanation of the concepts. The mean of the inquiry levels for the online simulation showed the online simulation at developing.

The EQUIP results of the simulation alongside of the scaffolding documents, and lesson plans provide an overview of level of inquiry and how the supports influence the inquiry level. Appendix I shows the results of these comparisons for Case 1. The simulation was always higher or at the same level of the scaffolding that teachers provided in their scaffolding documents and lesson plans. For example, as part of the instructional strategies element within the flower pollination simulation, students were not provided with notes. They had warm-up questions and other questions assessing their prior knowledge, and they had key terms to guide them throughout the simulation. The order of instruction element included exploration of the simulation lab with questions and observations and they were prompted to explain the process from those observations. Students were highly engaged with visuals and interactively manipulating while responding to questions throughout the simulation. The overall instruction of level of inquiry was exemplary.

Similarly, as part of the instructional strategies element, Jeannie asked the students to locate different flower parts such as the sepals and record how many of them were present in the flower. In the order of instruction element, she made the students explore the simulation with a diagram. The overall instruction of the level of inquiry was proficient. The lesson plan she provided was also proficient. She provided the students with notes and diagrams before the simulation. Order of instruction element was at preinquiry; she lectured and explained the concept. She utilized the “I do, you do, then we do” teaching framework and continued to ask students questions. Overall when compared, both the scaffolding documents and the lesson plan had an inquiry level of proficient and the simulation was higher, at exemplary. But since the EQUIP scores for the labs in Case 1 were higher than Case 2, the scaffolding documents and lesson plan activities for Case 2 were always lower than the lab itself.

Appendix J shows the results for Case 2. The results show that teachers did not use scaffolding documents with the simulation or the scaffolding teaching around the simulation to increase inquiry level, only to support the level of inquiry already in the written curriculum of the online lab. Both the simulation and the scaffolding documents used in conjunction with the simulation were at developing inquiry level. The level of inquiry in the simulation was much lower compared to the lesson plan. Both Dianne and Marlene used the frog simulation published from www.froguts.com with scaffolding documents provided. The instructional strategy element was rated proficient because the simulation provided the students with the purpose of dissection as a hook. Then they were asked to observe the frog to find similarities to the human body. Also, they watched a video clip on the history of the frog external and internal view of its body, and they had visuals of dissection tools and their functions. However, for the order of instruction element the simulation was at the preinquiry level, students had continually clicked on different icon to view the parts and arrow pointing to them and audio playing to explain their function. Students had constant audio explaining each part while they just clicked on the parts with no questions asked to check their understanding. The overall instruction of level of inquiry indicator for the virtual frog discussion simulation was developing.

In the same way, the lesson plan in Case 2 was at exemplary while the simulation at developing. See Appendix J. The lesson plan provided for this lesson was at the exemplary inquiry level, meaning that students were being exposed to higher inquiry levels in the activities the teachers had students do before, during, and after the simulation. For example, as part of the instructional strategies and order of instruction elements, Dianne and Marlene provided their students with a visual of the frog from the simulation. They told them to take five minutes to pair-share similarities to human anatomy, followed by another five minutes of think-aloud discussion of the list of major organs found in humans and frogs. They also completed a KWL chart, and a group activity with a Venn diagram for human and frog anatomy. Students were given ten minutes to review and write down definitions or functions of frog parts. Finally, the students were allowed to explore the simulation and reminded that they will have a hands-on dissection of the frog next class. Both elements were at the exemplary level of inquiry. However, the scaffolding documents used with the simulation was at developing. Students were given procedures to follow, which included when to click on specific parts to listen to their function as part of the instructional strategies element. The order of instruction element included students going through the simulation step by step using online tools. They were provided with images of the frog to label and multiple-choice questions to answer at the end of the simulation. To complete the lesson, students completed the hands-on frog dissection. They were assessed using daily assessment ticket and formative assessment to conclude. The scaffolding documents and lesson plan activities student experienced around the simulation lesson, improved the overall inquiry level. The overall instruction of level of inquiry was exemplary.

In addition to using the EQUIP to evaluate the levels of inquiry in the simulations and scaffolding documents, the content analysis of the simulations and scaffolding documents showed several components of the TUSI were incorporated in the simulations and scaffolding documents used in conjunction with the simulations. According the five guidelines that Flick and Bell (2000) proposed and Campbell and Abd-Hamid (2013) utilized to develop the TUSI model, teachers could integrate technology in science by doing the following: (a) introduce technology in the context of science content, (b) use it to address worthwhile science with appropriate pedagogy, (c) take advantage of its unique features, (d) utilize it to make scientific views more accessible, and (e) should be used to develop students understanding of the relationship between technology and science. The participants introduced technology in context of science content through simulations.

All the participants used simulations to support the development of scientific concepts and inquiry skills. In both Case1 and 2, participants used simulations to addressed science concepts based on the state and national science standards. Also, they used technology in the form of simulations to address worthwhile science with appropriate pedagogy by facilitating conceptual understanding of scientific process skills. Stewart used the scaffolding documents that came with the photosynthesis simulations.

These scaffolding documents also showed development of scientific inquiry skills. See Appendix I. Students develop a hypothesis prior to conducting the simulation. After manipulating the simulation to collect data, they used the data to develop conclusions. Also, the downloaded flower pollination simulation worksheet that came with the simulation in Appendix K for Case 1 included scientific process skills and literacy the students needed to develop. For example, in Activity A, they had to observe the steps of self-pollination, and in their own words describe the events in each step. However, Jeannie used the simulation as a prelab and provided the students with the scaffolding documents in Appendix J for the hands-on flower dissection after the simulation. The simulation EQUIP inquiry level was higher than the scaffolding documents provided for the flower pollination. Also, the photosynthesis scaffolding document was proficient while the flower pollination was at developing.

In Case 2, Dianne shared that she gives her students simulations to make concepts understandable for they have the visualization components already incorporated. Both Dianne and Marlene used the same frog simulation as a prelab before having the students complete the hands-on dissection. Marlene noted that simulations are powerful in aiding ELL students with understanding scientific concepts. She agreed that it takes a simulation to "bring the concept home" for the student. However, the frog simulation and scaffolding documents that came with it, contained limited scientific process skills and literacy as demonstrated in Appendix G. Also, the simulation and the scaffolding documents were at low inquiry levels based the EQUIP evaluation. The scaffolding documents contained the different organs from the frog that students had to click to view and describe their function. The teachers' pre-, during, and post instruction as well as their hands-on lab that followed the simulation reinforced the scientific inquiry skills and literacy. Students had to compare and contrast the observed simulated organs from the frog to the human body systems.

Furthermore, participants took advantage of the unique features of technology by using the visualization within the simulations to make the content understandable. They used the simulation during independent learning to allow students to interact with the content in more interactive ways, which also reinforce the relationship between science and technology. Three of the four participants used hands-on laboratory experiences after the simulation to ensure that students experienced the actual event, and know that simulations are not actual phenomenon (Campbell & Abd-Hamid, 2013). The simulations allowed the teachers to provide the students with actual representation of science concepts that appeared difficult. For example, Jeannie described her students observing self-pollination and cross-pollination of flowers, and Stewart noted that students were able to change the level of carbon dioxide and light frequency to comprehend their effects on photosynthesis. Students had the opportunity to test their ideas and acquire immediate results.

Moreover teachers used technology to make knowledge accessible to students. Stewart shared that technology allowed him to introduce difficult biological concepts such as the effect of toxin on; it would be difficult to bring it into the classroom, but a simulation would be the best alternative to teach the students the same concept. Also, Marlene added that simulations allowed her to expose the ELL students to biological concepts not otherwise possible due to the lack of resources in the classroom. Technology was incorporated in the science content through simulations to make the content comprehensible and accessible to ELL students.

Discrepant Data

For this multiple case study research, discrepant data are data that challenges congruency across the data sources and non-coding transcript. During data collection and analysis, some discrepant data challenged this congruency. All three sources of data for Case 1 were collected for both participants. While only one copy of scaffolding documents and lesson plan were collected for the two participants for Case 2. Although most of the data collected and analysis produced similar results, some discrepancies between the two cases were found. While three of the participants shared that they used simulations to improve ELL students' conceptual understanding of complex biological concepts. Steward shared that he used the simulations for simpler concepts because the students struggle with the more difficult ones. He used the simulation with photosynthesis, but share that he would not attempt simulations with harder concepts such as DNA replication and DNA translation because they are even more complex. Another discrepancy was that teachers at the site A reported using inquiry-based learning during the interview, but that was not evident in their lessons.

Summary

Chapter 4 included a description of the results for this study. Also, the research setting and participant demographics were described. Data collection procedures were discussed, which include the process of collecting the interview data, online simulation data, scaffolding documents, and lesson plans were collected. Data analysis procedures and use of the codebook were described. The results section was organized by research questions related to each theme within each case. In addition, the procedures followed to analyze the simulations and scaffolding documents. A discussion about the evidence of trustworthiness for this qualitative research related to the four constructs of credibility, transferability, dependability, and confirmability was also presented. For the cross-case analysis, emergent themes and discrepant data across all data sources were described in relation to the two cases. The results for this study were analyzed in relation to the component questions, related sub- questions, and the central research question.

In Chapter 5, the discussion, conclusions, and recommendations for the study are described. Also, an interpretation of the results is also discussed. Furthermore, Limitations for the study, recommendations for future research, and implications for social change are also presented.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this qualitative multiple case study was to explore how biology teachers support ELLs when using biology simulations to promote inquiry learning in high school biology classes within a school district in the southeastern region of the United States. The case study design befitted this study because it permitted me to examine the context and setting to offer a more in-depth understanding (see Stake, 1995; Yin, 2014) on how teachers support ELL students building inquiry skills in online biology simulations. The conceptual framework for this study included the constructivist perspective regarding the ZPD, EQUIP, and TUSI. Data collected from three sources, interviews, simulations, and documents, afforded me the opportunity to triangulate and converge multiple sources of data (see Yin, 2014). I conducted the study in relation to a gap in research, which indicated that there is a lack of understanding regarding how biology teachers leverage online simulations to promote inquiry learning with ELL learners. Though several researchers examined the use of simulations in science, minimal research addressed their uses with ELL students to promote inquiry. Several gaps also emerged from the reviewed literature in Chapter 2. Therefore, the data I collected and analyzed from this study showcased how the findings confirm, disconfirm, or extend such existing knowledge.

Using within and between case analyses, five themes emerged from the collected data sources. The first two themes, teacher awareness and ELL students' abilities and barriers, corresponded to the Component Question 1: How do teachers perceive ELL students' strengths and weaknesses in relation to inquiry learning using simulations? The remaining three themes, instructional assistance, pedagogical approaches, and virtual lab implementation were compatible with Component Question 2 and related subquestion 2.2: How does teacher scaffolding influence the level of inquiry for ELL students with each indicator of the EQUIP framework? In addition, results using the EQUIP from the stand-alone simulations, simulation documents, and lesson plans were used to answer this research question. Moreover, the simulations provided data from the content analysis of the simulations and simulation documents concerning to the TUSI model. In relation to the central research question and the conceptual framework, the themes that corresponded to Research Question 1 were aligned with the EQUIP model, while both the EQUIP and TUSI models as well as the constructivism perspective ZPD corresponded to Research Question 2. I begin this chapter with an interpretation of the findings in relation to the reviewed literature, central research question, and conceptual framework of the study followed by the limitations of the study and recommendations for future research; I conclude with a description of social implications of social change of the findings.

Interpretation of the Findings

In this section, I present the interpretation of the findings for central research questions, the component questions, and related subquestions of the qualitative multiple case study. I interpreted the results based on themes related to the research questions and the conceptual framework. I also interpreted some of the findings from the current study to confirm, disconfirm, or extend the findings from the literature.

Component Question 1

Component Question 1 was as follows: How do teachers perceive ELL students' strengths and weaknesses in relation to inquiry learning using simulations? The findings for the first component question corresponded to two themes: teacher awareness and ELL students' abilities and barriers. Teachers perceived several advantages and disadvantages of simulations when used with ELL students. Previous research supports that teacher perceptions affect their instructional practices (Britzman, 1998, 2012; Deemer, 2004; Farrell & Ives, 2015; Sugimoto, Carter, & Stoehr 2017; Tsui, 2007). Teachers' perceptions of ELL students in my study were related to their perceptions on simulations with ELL students during inquiry-based learning. They perceived that simulations are user-friendly and easier to modify than hands-on or physical labs. Several researchers focused on the advantages and disadvantages of simulations (Bonser et al., 2013; De Jong et al., 2013; Hew & Cheung, 2010; Lerner, 2016; Milner 2001). Bonser et al. (2013) concurred that simulated labs could accommodate the needs of diverse learners. They can also be tailored and adapted for diverse students who need more time (De Jong et al., 2013; Milner, 2001). On the other hand, teachers of ELL students in my study believed that sometimes an ELL student lacked technology experiences that may reduce the benefits of the simulation experiences. A review of the literature on ELLs and technology revealed that many students do not have technology access due the digital divide among learners of various socioeconomic backgrounds (Darling-Hammond et al., 2014; Hur & Suh, 2012; Koyunlu et al., 2014; Lee & Tsai, 2013; Ryoo, 2015; Sox & Rubinstein-Avlila, 2009). Results from my study confirm that an ELL student's lack of technology experiences may diminish their simulations experiences and extend on the current research in understanding teachers' perceptions in relation to the use of simulations with ELL students.

The second theme related to Research Question 1 was ELL students' abilities and barriers. One conclusion that came from the data related to this theme and Component Question 1 was teachers that believed that ELL students benefited from inquiry simulations because of their ability to interactively manipulate the program. The research supports having learners immersed in the learning process to construct meanings. This is in accordance with Dickey (2011), who noted that meaningful and active learning occur in complex, multimodel environments in which the students partake in the knowledge construction process. In addition, virtual labs allow students to virtually manipulate the type of scientific equipment that may not be found the physical classroom (Heradio et al., 2016). In addition, the findings from this study indicated that ELLs could recognize the visuals in the simulations. This finding confirms that simulations present students with visuals or invented scientific phenomena and representation of nonphysical concepts (Botzer & Reiner, 2005). Furthermore, recent researchers have underscored the significance of making thinking visible in complex situations to promote meaningful learning (Wang, Derry, & Ge, 2017; Wang, Kirschner, & Bridges, 2016). Ryoo (2015) developed interactive, web-based lessons that included activities with visualizations, audio narration, and informational texts that allowed students to explore unseen, abstract processes of the concepts. Through this approach, students could comprehend the concepts at various English proficiency levels. Adams et al. (2015) also agreed that visual support fosters language acquisition.

Furthermore, the results showed that teachers believed that ELL students struggle with the English language and reading, which influence their inquiry thinking during science simulations. Abbott (2014) agreed that ELL students struggle with various courses that require high academic demands. The findings also revealed that they have prior knowledge, which Fránquiz and Salinas (2013) confirmed. Researchers have shown that ELLs also excel in science when the inquiry-based is used with language integration and appropriate scaffolding strategies (Ardasheva et al., 2015; Belland et al., 2013; Buxton & Lee, 2014; Echevarria & Short, 2011; Swanson et al., 2014). The results are also supported by several researchers who suggested giving ELL students extra time (Allen & Park, 2011; Cummins, 2001). Researchers have shown that even though ELL students could follow directives and partake in what he called BICS, which takes 1 to 3 years to develop, they are ready for the CALP between 5 to 7 years (Allen & Park, 2011; Cummins, 2001). Based on results of this study, in addition to Abbott (2014), Allen and Park (2011), Cummins (2001), and Fránquiz and Salinas (2013), teachers may have the expectation that ELL students may experience difficulties with the English language that influences their inquiry thinking during science simulations when they have not had the time for CALP. The results of the study extend the understanding that language teaching needs to center more on the CALP instead of the BICS, which ELL students require to succeed academically.

Moreover, findings from my study revealed that teachers notice ELL students' trepidation toward participating in class because of their accent, especially in mainstream classes. Jenkins (2014) noted for the past decades that accent has been one of the areas studied in the field of second language acquisition. Researchers have also explored the prospects of attaining native accent, which Wang (2013) has dismissed. Reaching a native-like accent is idealistic during the process of acquiring a second language. In a qualitative study, Kung and Wang (2018) determined that ELLs aimed to speak like a native English speaker. The findings from this study revealed that teachers believed that students have trepidation about their accents, which may hinder their participation in the science classroom and being immerse in the inquiry learning process.

Component Question 2

The second component question was as follows: How does teacher scaffolding influence the level of inquiry for ELL students with each indicator of the EQUIP framework? The findings for the second component question corresponded to three themes: instructional assistance, pedagogical approaches, and virtual lab implementation. The first theme of instructional assistance had four sub themes of (a) accommodations, (b) preinstruction, (c) during instruction, and (d) postinstruction. It also included the findings from the simulations, scaffolding documents, and lesson plans.

Related Subquestion 2.1

The first findings that came from the data related to how teachers describe their scaffolding to support ELL students' inquiry learning during the implementation of biology simulations was that teachers believed ELL students needed accommodations, such as translation and additional time, to comprehend what they are experiencing during the implementation of biology simulations to arrive at their ZPD. Several researchers confirmed that ELL students benefit from accommodations customized for their linguistics and cognitive needs (Abedi, 2014; Ardasheva et al., 2015). Other researchers have shown that some simulations already have the built-in time for ELL students to work at their own pace (Cappatore et al., 2015; Heradio et al., 2016; Karakasidis, 2013; Ryoo, 2015). In this study, I revealed that biology teachers believed allowing ELL students to use their phones and providing them with translation websites are also important in supporting their inquiry learning when implementing biology simulations to support their progression towards ZPD.

The second conclusion from the data were that teachers believed that incorporating scaffolding strategies in the form of preinstruction such as visuals, prereading, and diagrams activated their prior knowledge in preparation the inquiry simulation experience. Similarly, Kukkonen et al. (2014) affirmed that that when inquiry-based learning coupled with simulations and proper scaffolding strategies are used, students could construct knowledge and achieve learning success. Also, providing them with scaffolding support early facilitates learning and allows them to create their meaning (Jumaat & Tasir, 2014). Based on the constructivist perspective, learners' ZPD varies as they learn and construct meaning. While Short et al. (2012) found that frontloading ELL students with vocabulary to build their background knowledge to be accurate; teachers from my study believed that reloading may be more effective. Silva et al. (2013) confirmed that reloading ELLs with critical terminologies has proven effective because language is situated in the meaning of vocabulary words within the context of the lesson, and the focusing on science vocabulary in isolation is dissuaded (NGSS Lead States, 2013).

Zhang and Li (2014) found that simulations provide learners with the freedom to err and in learn from their mistakes in the learning process by repeating the simulations as many times as they need to understand the concepts (Zhang & Li, 2014). Teachers from my study believed that in addition to understanding the science concepts, ELL students may acquire the BICS and the CALP through collaborative learning and repeating simulations. Aydin (2016) confirmed communication skills improved with collaboration. Though science learning is difficult for ELL students because of the time needed to acquire the academic language proficiency (Cummins, 2001), they still need to be engaged in science practices that incorporate scientific sense-making (Aronson & Laughter, 2016). Terrazas-Arellanes, Gallard, Strycker, and Walden (2018) in a 3-year study that involved interactive online middle school science units, found that the online units significant deepened ELL students' scientific knowledge. Their study indicated that these lessons helped to improve academic science vocabulary and decrease the science literacy gap for ELL students. My study confirms that it may also apply to high school ELL students. Also, studies have shown that differentiating instruction through virtual learning fosters autonomous learning, improve confidence in learning, and promote collaboration (Vargas-Parra, Rodríguez-Orejuela, & Herrera-Mosquera, 2018). Results from my study confirmed that biology teacher used differentiated instruction to encourage ELL students to work independently and collaboratively using simulations, which also appeared to make students more confident about learning science content.

Related Subquestion 2.2

Concerning how teachers use online simulations to make scientific inquiry understandable to ELL students, several studies showed that simulations could be used as prelabs activities (Davis & Berland, 2013; Dewprashad & Persaud 2015; Makransky et al., 2016). Also, Davis and Berland (2013) conceded on the significance of simulations in promoting laboratory skills. While the first findings confirmed that teachers use simulations as prelabs to enhance ELL students' background knowledge and scientific skills before the physical laboratory experiences, biology teachers from my study also believe ELL students could benefit more from the simulation experience and improve their science content skills with additional scaffolding. Bell et al. (2005) remarked that scaffolding strategies are needed to help students progress to advanced inquiry skills. However, findings from my study revealed using the scaffolding documents provided with the online simulations may not improve the inquiry learning experiences for ELL students. Therefore, the teachers' role during the implementation of the simulation could have an impact on the inquiry level.

The results also showed that teachers use simulations to build and strengthen the scientific and conceptual understanding of ELL students. Rutten et al. (2012) confirmed that simulations foster learner's discovery and deepen essential science concepts. Also, Lindgreen and Tscholl (2014) contended that simulations challenge learners' misconceptions, while simultaneously providing opportunities for remediation

(Lindgreen & Tscholl, 2014). Findings from my study confirm that biology teachers believe this to be true. Furthermore, research showed that simulations make science knowledge accessible and feasible for learners (Altalbe et al., 2015; Campbell & Abd-Hamid, 2013; Lang 2012; Metcalf et al., 2013; Myneni et al., 2013; Olympiou, Zacharias, & De Jong, 2013; Zacharia & Olympiou, 2011), and they are more accessible than physical labs (Brinson, 2015; De Jong et al., 2013). Results from my study revealed that biology teachers use simulations to make science inquiry concepts knowledge accessible to ELL students without the availability of certain resources from their classrooms.

Related Subquestion 2.3

Results from the data regarding the level of inquiry teachers address in biology simulations for ELL students based on the indicators of the EQUIP framework revealed that some simulations are at higher inquiry levels than others and using scaffolding documents may increase or decrease the inquiry levels. The EQUIP has been used to measure the levels of inquiry within science instruction in several studies (Henderson-Rosser 2015; Gormally et al., 2016; Oppong-Nuako et al., 2015; Radišić, and Jošić, 2015). The findings of my study are confirmed by Henderson-Rosser (2015) study, which combined the EQUIP and TUSI models of the conceptual framework. Henderson-Rosser (2015) study showed that technology is integrated to enhance already occurring inquiry instruction, and that technology-based strategies are needed to support collaboration and active learning to achieve exemplary inquiry level. These results also applied to TUSI, noting that technology is used to enhance the teachers' role during inquiry-based learning to guide learners reflect on the relatedness of the tool to the scientific concept to arrive at exemplary inquiry. Campbell & Abd-Hamid, (2013) noted that hands-on laboratory experiences are needed following simulations. The biology teachers in my study used hands-on laboratory experiences after the simulation to ensure that students experienced the actual event, and know that simulations are not actual phenomenon.

Limitations of the Study

The case study qualitative research design has inherent limitations, such as subjectivity and lack of reliability, validity, and generalizability. Limitations were identified in relation to the research design for this study. Generalization in using the case study research described by Yin (2014) is not possible for two reasons. First, generalization of the research findings is not achievable based on the sample size of four participants in the study. Second, Yin (2014) contented that four to six cases are needed to create theoretical replication, and this study only contained two cases.

Another limitation is related to the time allowed for data collection. The data collection timeframe for this study was six weeks. Teachers provided title and URL of simulations that they used with their ELL students via email. Also, I collected scaffolding documents and lesson plans prior to conducting individual interviews. Though I conducted four individual interviews, but only three simulations were analyzed. Analysis of three simulations may not provide sufficient information in grasping how biology teachers support ELL students when using online biology simulations to promote inquiry learning. Analysis of multiple simulations would have provided extensive data to answer the research question.

The third limitation is related to participants. A small sample size of four teachers participated in the study. The participants were high school biology teachers who had ELL students and use simulations. Consequently, the results for this study may not be representative of all biology teachers with ELL students and used simulation within a school district in the southeastern region of the United States.

Recommendations for Future Research

Recommendations for further research are based on study results and limitations of the study. The first recommendation is related to the limitations. Researchers could replicate this study by recruiting participants to get a sample larger than four biology teachers who teach ELL students and use biology online simulations. Also, they could utilize more than two cases to better be able to generalize their findings. Choosing to follow this recommendation would provide better understanding on how biology teachers support ELL students when using online biology simulations to promote inquiry learning.

The second recommendation is related to the findings revealing that teachers believe that ELL students struggle with the English language and reading which influence their inquiry thinking during science simulations. ELL students were from different language proficiency levels. Also, they were exposed to three different simulations. Therefore more research needs to be done with ELL students at the same language proficiency and using the same simulation, so that deeper understanding of their literacy abilities and barriers with inquiry learning when simulations are used.

The last recommendation is concerning me being the sole researcher conducting content analysis using Marshall et al. (2009) Electronic Quality of Inquiry Protocol

(EQUIP). This study was conducted by one researcher using the EQUIP to measure the levels of inquiry of ELL students in online simulations, scaffolding documents, and lesson plans. Conducting the same study in collaboration with multiple researchers using the same protocol to measure the levels of inquiry in online simulations, scaffolding documents, and lesson plans could add to the understanding of inquiry learning.

Implications for Social Change

The results from this study provide several contributions to positive social change. First at the individual level, this study has the potential to be innovative as biology teachers used simulations to help determine the levels of inquiry in science learning.
It is possible that being included in this study, reflecting on the answers to questions asked in the interviews may have helped teaching individually process their pedagogical practices and may lead them to thoughtful changes they could make to improve their own instruction to ELL students using simulations. The biology teachers in my study integrated technology in the form of simulations to support inquiry learning with ELL students. The findings revealed teachers' perceptions of ELL students sometimes lacked technology experiences that would reduce the benefits of the simulation experiences. Previous research showed that both teachers and students benefit from technology integration (Campbell et al., 2015). Also, Fullan (2013) noted that the integration of technology coupled with the appropriate pedagogy can open students and teachers to entirely new learning prospects. The findings for this study not only add to instructional insights for teachers but may aide to improved technology integration with ELL students.

The second contribution that this study makes to positive social is at the organizational level. This study has the potential to improve the educational field. The findings from the study indicated that incorporating scaffolding strategies in the form of pre-instruction such as visuals, pre-reading, and diagrams activated prior knowledge of ELL students in preparation for the inquiry simulation experience. This finding is in accordance with the study from Kukkonen et al. (2014) about inquiry-based learning coupled with simulations and proper scaffolding strategies, and Jumaat and Tasir, (2014) about providing ELL students with scaffolding support meaning construction. This study may increase the understanding of biology simulations and the scaffolding that occurs around the implementation foster inquiry learning. Also, the findings of this study may provide education professionals options regarding the implementation of biology simulations to support ELL students in acquiring inquiry skills in innovative ways. This study also advances knowledge in the field of Learning, Instruction, and Innovation because simulations were used as a novel approach to determine the levels of inquiry learning with ELL students.

The last contribution that this study makes to positive social is at the societal level. The findings showed that teachers use simulations to build and strengthen conceptual scientific understanding in ELL students. Rutten et al. (2012) confirmed that simulations foster learner's discovery and deepen essential science concepts. Furthermore, research showed that simulations make science knowledge accessible and feasible for learners (Altalbe et al., 2015; Campbell & Abd-Hamid, 2013; Lang 2012; Metcalf et al., 2013; Myneni et al., 2013; Olympiou et al., 2013; Zacharia & Olympiou, 2011), and they are more accessible than physical labs (Brinson, 2015; De Jong et al., 2013). Results from my study revealed that biology teachers use simulations to make science concepts knowledge accessible to ELL students without the availability of certain resources from their classrooms. The findings of this study may provide teachers with the resources to cater to ELL students' needs, which may help to close the educational achievement gap of the underprepared ELL population to equip them with the inquiry skills them better for the science field or the workforce.

Conclusion

The results of this study were interpreted from a constructivist perspective, specifically ZPD, the EQUIP model, and the TUSI model offer an innovative approach in exploring ELL students' inquiry learning with the integration of technology. Several researchers have conducted studies related to the constructivism theory and inquiry-based learning in science with ELL students using various inquiry models (Quigley et al., 2011; Zion & Mendelovici, 2012). Others have focused on ELL students in relation to language acquisition (Adams et al., 2015;Ardasheva et al., 2015; Buxton & Lee, 2014; Tong, Irby, Lara-Alecio, & Koch, 2014; Lara-Alecio et al., 2018), technology integration (Campbell & Abd-Hamid, 2013; Campbell et al., 2015; Fullan, 2013; Koehler et al., 2014; Mishra & Koehler, 2006), as well as computer simulations (Achuthan et al., 2014; Brinson, 2015; Darling-Hammond et al., 2014; De Jong et al., 2013; Furtak et al., 2012; Kukkonen et al., 2014; Lee & Tsai, 2013; Rutten et al., 2012; Sarabando et al., 2014; Slavin et al., 2014; Toth et al., 2014; Winsberg, 2015; Zhang & Li, 2014). However, the findings of this study confirm that ELL student require more technology experiences, scaffolding strategies, and literacy support to enhance their simulations inquiry experiences that better support reaching their ZPD. Also, the results show that simulations have the potential to improve ELL students' background knowledge, inquiry skills, and strengthen conceptual understanding with additional scaffolding based on the EQUIP. Thus, the findings of this study extend the understanding that biology teachers use technology and scaffolding strategies to foster ELL students' inquiry learning. Findings from my study have the potential to impact how biology teachers implement simulations to promote inquiry learning with ELL students in their classes, in the school, and in the fields of science education, technology in education, and English language learning.

In today's society, technology and inquiry skills are critical to academic and professional success. There is an overwhelming need for students trained in Science Technology Engineering and Mathematics (STEM) (Castleman, Long, & Mabel, 2018). Research showed that the number of STEM jobs has increased tremendously. The mathematical science occupations group is at 28.2 percent and STEM employment is predicted to continue growing over the next decade (Fayer, Lacey, & Watson, 2017; Noonan, 2017). Unfortunately, many English ELLs are at a disadvantage in relation to technology and science. While the number of ELLs is growing (National Center of Education Statistics, 2018), and technology integration has been proven to enhance already occurring inquiry instruction (Henderson-Rosser, 2015), the achievement gap between ELL students and their peers in science education continues. This study has contributed understanding to this societal problem by providing insight that may increase understanding of how biology teachers support ELLs when using technology in the form of simulations to promote inquiry learning.

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Appendix A: Interview Protocol

PART 1: DEMOGRAPHIC QUESTIONNAIRE

Your Name:
Your Teaching Licensure:
Current Teaching Assignment:
Background How long have you been teaching? Aside from biology, what other content areas have you taught, if any? Have you taught ELL students? Do you currently have ELL students in your classes? How would you define inquiry learning in your classroom? What types of online simulations have you used with your ELL students?

PART 2: SIMULATION REQUEST QUESTIONNAIRE

Please briefly describe any modification strategies you have used with ELLs.
Please share with me a lesson simulation title and URL you will be using or have used with your students in last three months? **Lesson Simulation Title:** **Lesson Simulation URL:** Any time within the next two to three weeks, please share with me a copy of your lesson plan, including any modifications or supportive documents you use with students, and the simulation handout from the online lab, which may take about 30 minutes of your time. Please send as email attachments to XXX@waldenu.edu.

PART 3: INTERVEW PROTOCOL

Date of Interview	Participant Label:	
Interview questions	Follow-up questions	Field Notes
1. Describe the strengths and challenges you have observed in how ELLs handle simulation inquiry learning.	1. What strengths or advantages do ELLs have in relation to inquiry learning via simulations? 2. What challenges do ELLs have in relation to inquiry learning via simulations? 3. Could you share an example of how the use of simulation particularly helped or hindered an ELLs inquiry experience?	
2. In relation to using your selected simulation, describe any instruction, resources, class activities, assignment modifications, or supplementary handouts you provide for ELLs to support their simulation experience.	1. Could you describe any additional face-to-face discussions you facilitate as a whole group or discussions you monitor while students are in small groups? 2. Describe any additional pre, during, or after strategies you provide (like prelab or postlab questions) that are not included as part of the simulation. How successful have these strategies been, specifically with ELLs? 3. Please describe any additional support you may provide ELLs (modifications, vocabulary terms etc.) as part of their experience? 4. Describe why you developed additional supports for the simulation. How successful have these supports been for ELLs?	

3. Describe how the use of online simulations in the laboratory support ELL students' understanding of scientific concepts	1. How well do you feel that the online simulation supports the development of scientific (inquiry) with ELLs? 2. Why did you choose to use the simulation instead of a hands-on classroom laboratory experience? 3. In your experience with using online simulations, how well do you believe the simulations make difficult science concepts more understandable for ELL students? 4. In what ways have you found that a simulation allows ELLs students to experience or learn, that they couldn't in other ways?	

Appendix B: EQUIP Simulation Data Collection Form

Online Simulation FORM		
Date:		
Time:		
Name of Online Simulation: **URL:**		
Criteria		
Purpose of Simulation		
Topic/Content of Simulation		
Levels of Inquiry in EQUIP		
Instructional Strategies	Preinquiry Developing Proficient Exemplary	Notes of Evidence:
Order of Instruction	Preinquiry Developing Proficient Exemplary	Notes of Evidence:
Teacher Role	Preinquiry Developing Proficient Exemplary	Notes of Evidence:
Student Role	Preinquiry Developing Proficient Exemplary	Notes of Evidence:
Knowledge Acquisition	Preinquiry Developing Proficient Exemplary	Notes of Evidence:
Overall Instruction of Level of Inquiry		
Questioning Level	Preinquiry Developing Proficient Exemplary	Notes of Evidence:
Complexity of Questions	Preinquiry Developing Proficient	Notes of Evidence:

	Exemplary	
Questioning Ecology	Preinquiry Developing Proficient Exemplary	Notes of Evidence:
Overall Discourse of Level of Inquiry		
Content Depth	Preinquiry Developing Proficient Exemplary inquiry	Notes of Evidence:
Learner Centrality	Preinquiry Developing Proficient Exemplary inquiry	Notes of Evidence:
Standards	Preinquiry Developing Proficient Exemplary inquiry	Notes of Evidence:
Organizing and Recording Information	Preinquiry Developing Proficient Exemplary inquiry	Notes of Evidence:
Overall Assessment of Level of Inquiry		
Prior Knowledge	Preinquiry Developing Proficient Exemplary inquiry	Notes of Evidence:
Conceptual Development	Preinquiry Developing Proficient Exemplary inquiry	Notes of Evidence:
Student Reflection	Preinquiry Developing Proficient Exemplary inquiry	Notes of Evidence:
Overall Curriculum of Level of Inquiry		

Appendix C: Scaffolding Resource Data Collection Form

Scaffolding Resource FORM	
Date:	
Time:	
Title of Resource(s):	
Criteria	
Purpose of Scaffolding resource	
Topic/Content of Scaffolding resource	
Levels of Inquiry in EQUIP	
Instructional Strategies	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Order of Instruction	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Teacher Role	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Student Role	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Knowledge Acquisition	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Overall Instruction of Level of Inquiry	
Questioning Level	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Complexity of Questions	Preinquiry Notes of Evidence: Developing

	Proficient Exemplary inquiry
Questioning Ecology	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Overall Discourse of Level of Inquiry	
Content Depth	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Learner Centrality	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Standards	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Organizing and Recording Information	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Overall Assessment of Level of Inquiry	
Prior Knowledge	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Conceptual Development	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Student Reflection	Preinquiry Notes of Evidence: Developing Proficient Exemplary inquiry
Overall Curriculum of Level of Inquiry	

Appendix D: Simulation + Scaffolding Resource Document Data Collection Form

Simulation and Scaffolding Resource FORM	
Date:	
Time:	
	Description of evaluation of the differences in level of inquiry between simulation alone, and simulation + scaffolding related to the student experience. (Did scaffolding change the inquiry experience for students?)
Category	
Instruction	
Discourse	
Assessment	
Curriculum	
Technology Use	
Interview Questions	

Appendix E: Codebook

Codes	**Definitions**
Accommodations	Students have access to dictionaries, Google translate, phones, paraprofessional and teacher for language translation during instruction and simulations
	Students are given additional time to complete assignments and assessments. Teacher reads to students to help understand English.
Collaborative Learning	Involves students working or discussing in pairs, partners, grouping students based on specific criteria to interact during instruction
Collegial Collaboration	Teachers working together in small learning community PLC or participating in workshops
Content Assessment	Teachers asking students to use illustrations to show understanding,
	Using Exit Tickets, projects, self-check questions, quizzes and test to test students' comprehension
Cooperative Learning	Assign students roles and give each participant point for completing their part.
Building Conceptual understanding	Using demonstrations, follow-up questions, revised thinking, make connections from parts to whole, and simulations
ELL Challenges	ELL students' English proficiency varies
	Afraid to raise hands or participate due to accent
	Struggle with reading, bookwork, and content vocabulary
	Lengthy instructions, complicated simulations, and homework assignments
ELL Strengths	ELL students know how to label pictures/diagrams
	Show prior knowledge of common things, recognize images, do hands-on activity and feel comfortable with simulations
Gaps in Learning	Got stumped with technical words, lack of schooling from home country, compliance. The instructional needs are greater than regular students.
Hands-on Lab	Provide predictable results, involve completing steps

Inquiry	Teachers' or students leading the learning process with questions Teacher-led inquiry or student-led
Teaching Approach	Methods the teacher uses to deliver the lesson, such as differentiated instruction, lectures, simulations, hands-on
Instructional Support Strategies	Strategies used to motivate or students understands and deepen their knowledge, such as captions from videos, pausing videos frequently, thinking skills, additional guidance, visual cues, examples, models, and websites.
Interactivity	Students interact with the simulation and feel as part of the simulations, control and manipulate the activity on their own
Lack of Resources	Teachers not having access to instructional resources in the classroom such as dictionaries and computer.
Lack of Conceptual Knowledge/Understanding	ELL students lacking comprehension in English, lack content exposure, communication and technological skills with simulations sometimes not related to language barrier.
Language Challenges	ELL students struggle with the English language, have low proficiency, accent, BICS and CALP in language acquisition.
Modifications	Assisting ELL students to get the content by meeting their needs with fair activities and assessments, such as breaking complex assignments to manageable parts.
Monitoring Learning	What teacher does to during their instruction to assure that learning is taking place, such as using checklists, learning scales and assigning points
Post Instruction	Strategies or activities after instruction such as tests, quizzes, essays, and remediation

Pre-Instruction	Strategies the teachers use before delivery their lesson such as using cognates, root words, frontload, brainstorming techniques. Including visuals (charts-KWL, diagrams, pictures, samples, graphic organizers) vocabulary words
During Instruction	Strategies the teachers use while proceeding with instruction such as asking analysis questions. How teachers facilitate or monitor their instruction.
Repetition	Allowing students to repeat the same activities, replay simulations, or refresh videos
Scaffolding	Chunking to make content comprehensible to students.
Simulation Benefits	How and why teachers use simulations within their lessons to improve students learning, such as using simulations as prelab or they are easier to modify
Simulation Drawback	Teachers view simulations as lack of reality, provide limited results and complicated-not helping students learn the concepts.
Teachers Activate Prior Knowledge	Teachers ask prompted questions, probing questions, or use short videos to check students' knowledge before teaching their lessons.
Perceptions on simulations	How teachers view simulations, such as students perceive students playing video games, different from virtual labs, powerful tool and user friendly, not language dependent

Appendix F: Themes Identified From Second Cycle Coding Strategies for All Data Sources Aligned to Research Questions

Research Question	Second cycle categories per case	Themes

RQ1. How do teachers perceive ELL students' strengths and weaknesses in relation to inquiry learning using simulations?	**Case 1—** ▪ Lacking computer resource ▪ Teacher's perceptions ▪ Simulation benefits ▪ Simulation drawbacks **Case 2—** ▪ Teacher's perceptions ▪ Simulation benefits ▪ Simulation drawbacks	Teacher awareness
	Case 1— ▪ Gaps in learning ▪ interactive with simulations ▪ ELL strengths ▪ ELL challenges ▪ ELLs Struggle with reading ▪ Lacking conceptual knowledge ▪ Lacking content knowledge ▪ Language barrier **Case 2—** ▪ Gaps in learning ▪ interactive with simulations ▪ ELL strengths ▪ ELL challenges ▪ ELLs Struggle with reading ▪ Lacking conceptual knowledge ▪ Lacking content knowledge ▪ Language barrier ▪ Lacking computer skills ▪ Lacking accommodations during lectures	ELL students' abilities and barriers
RSQ 2.1. How do teachers describe their scaffolding to support ELL	**Case 1—** ▪ Accommodations **Case 2—** ▪ Accommodations	Instructional Assistance a) Accommodations

students' inquiry learning during the implementation of biology simulations?	**Case 1—** ▪ Teacher's visualization ▪ Visualization from simulations ▪ Pre-reading ▪ Teacher activates prior knowledge **Case 2—** ▪ Teacher's visualization ▪ Simulation visualization ▪ Scaffolding ▪ Teacher activates prior knowledge	b) Pre-instruction
	Case 1— ▪ Instructional support ▪ Monitoring learning ▪ Teacher facilitates learning ▪ Scaffolding ▪ Visualization from simulations **Case 2—** ▪ Instructional support ▪ Monitoring learning ▪ Teacher facilitates learning ▪ Scaffolding ▪ Repetition	c) During instruction
	Case 1— ▪ Content assessment ▪ Remediation **Case 2—** ▪ Content assessment ▪ Post lab questions ▪ Teacher's feedback	d) Post instruction
	Case 1— ▪ Collaborative learning ▪ Independent learning ▪ Inquiry ▪ Differentiated instruction ▪ Modifications	Pedagogical approaches

	▪ Hands-on ▪ Simulations ▪ Professional learning **Case 2—** ▪ Collaborative learning ▪ Independent learning ▪ Inquiry ▪ Differentiated instruction ▪ Cooperative learning ▪ Modifications ▪ Hands-on ▪ Simulations ▪ Professional learning	
RSQ2.2. How do teachers use online simulations to make scientific inquiry understandable to ELL students?	**Case 1—** ▪ Pre-Lab ▪ Simulation benefits ▪ Building conceptual understanding **Case 2—** ▪ Pre-Lab ▪ Simulation benefits ▪ Building conceptual understanding	Virtual lab implementation

Appendix G: Case 2 Scaffolding Documents

Name: ________Ms. Dianne and Ms. Marlene__________

Virtual Lab: Virtual Frog Dissection
Post-Lab Quiz and Lab Report

1. If you come upon any terms that are unfamiliar to you, please refer to your textbook for further explanation or search the word here: http://encarta.msn.com/encnet/features/dictionary/dictionaryhome.aspx
2. In this exercise, you will be performing a virtual frog dissection. To begin, click on the "Introduction" link on the opening page. Read through and listen to the information presented to learn about the basics of dissection and animal phylogeny. When you are finished, click the "Menu" button at the bottom of the page to return to the opening page of the laboratory activity.
3. Once you are back to the opening page, click the "External Anatomy" button. Read through, watch and listen to the information presented in these segments. When you are finished, click the "Menu" button at the bottom of the page to return to the opening page of the laboratory activity.
4. The last portion of this activity involves an examination of the internal anatomy of a frog. To do this, click the "Internal Anatomy" button on the opening page of the laboratory. Read through, watch and listen to all of the information presented in these segments and actively participate where required. You may have to do a virtual cut on the frog by dragging the appropriate tool to the frog or label organs of the dissected frog by dragging the appropriate organ names to the site on the opened frog. Please **STOP**

when you are through with each labeling step and be sure to fill in your final answers on Figures 1 and 2 below.

5. When you are through opening all of the segments in the "Internal Anatomy" section, you will have successfully completed the virtual dissection.
6. Please finish this learning exercise by opening the "Journal" link at the bottom of the page and answering the questions.

Figure 1: Digestive System Organs

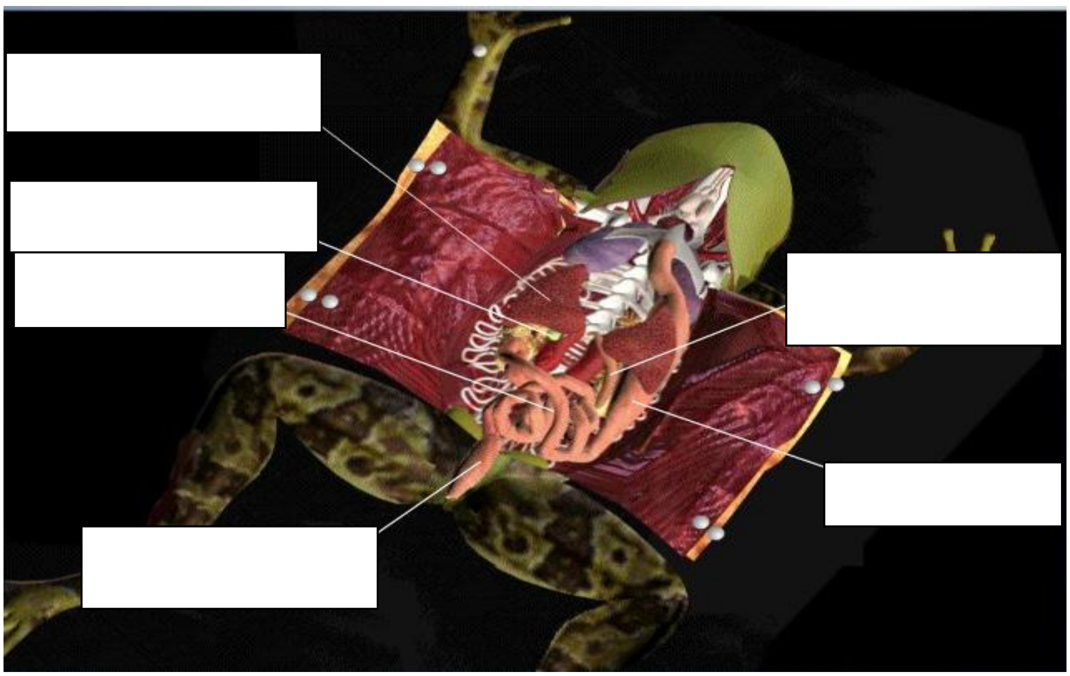
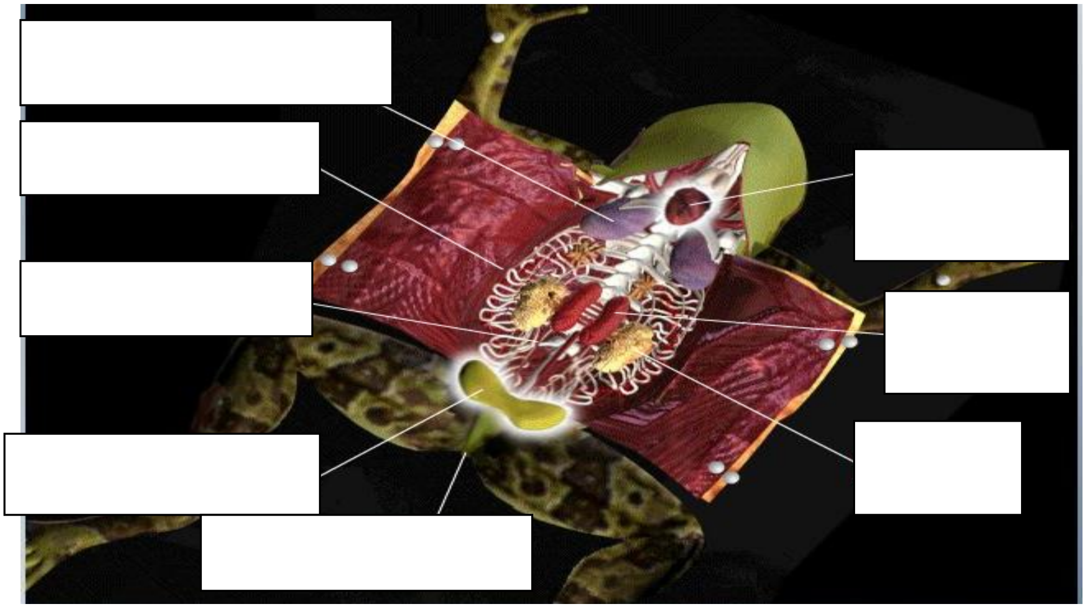


Figure 2: Organs of the Circulatory, Respiratory, Excretory and Reproductive Systems



Post-laboratory Questions:

1. The dorsal side of the leopard frog:
   a. Is a light, solid color
   b. Is a colored and patterned
   c. Is initially cut during a dissection
   d. A and C
2. Leopard frogs:
   a. Are invertebrates
   b. Are warm-blooded
   c. Have a gills at one time during their life cycle
   d. All of the above
3. In regards to the external anatomy of a leopard frog:
   a. It is easy to tell the sex of the animal
   b. The cloaca is at the anterior end of the animal
   c. The feet of the hind limbs have 5 toes
   d. All of the above
4. In the opened mouth of the leopard frog, one can see:
   a. The nostrils
   b. The glottis
   c. The vomerine teeth
   d. A and B
   e. All of the above
5. Which of the following is found in the digestive system of the leopard frog but not in that of a human?
   a. Gall bladder
   b. Stomach
   c. Pancreas
   d. Liver
   e. None of the above
6. Arteries in the circulatory system:
   a. Carry blood to the heart

b. Carry blood away from the heart
c. Carry out diffusion of gases

7. In the leopard frog heart:
a. The right atrium carries oxygen rich blood
b. The left atrium carries oxygen poor blood
c. There are 3 chambers present
d. All of the above

8. By comparison to the leopard frog heart, the human heart:
a. Has 4 chambers present
b. Carries mixed blood in the ventricles
c. Is more efficient
d. A and C
e. All of the above

9. Fat bodies play a role in:
a. Respiration
b. Circulation
c. Hibernation
d. Reproduction
e. C and D

10. The most anterior portion of the leopard frog brain is/are the:
a. Olfactory lobes b. Cerebrum c. Optic lobes

Name______Dianne and Marlene

Virtual Frog Dissection Worksheet

1. Go to www.froguts.com

Select DEMO at the top. Select VIEW DEMO at the bottom of the screen. Go through step by step using online tools.

<u>Exterior observations :</u> Describe each organ/system as program guides you -

1) Frog skin –

2) Nictitating Membrane –

3) External nares –

4) Tympanum –

5) Leg adaptations –

6) Cloaca –

7) **Male frog characteristics –**

8) **Female frog characteristics -**

Follow instructions and click on parts as you are instructed. Describe each. USE COMPLETE SENTENCES!!!

a) **Abdominal cavity –**

b) **Thoracic cavity –**

c) **Heart –**

d) **Liver –**

e) **Stomach –**

f) **Small intestine –**

g) **Large intestine –**

h) **Lungs –**

i) **Bladder –**

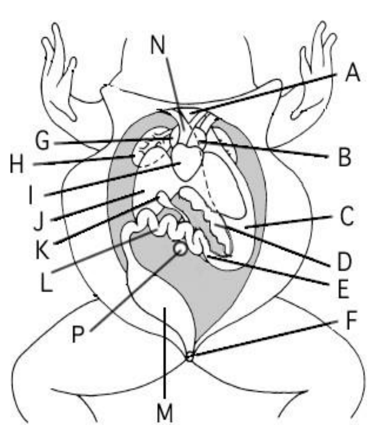
2. Go to http://www.biologyjunction.com/frog_dissection.htm - use the information here to complete the following questions.

Questions:

1. The membrane that holds the coils of the small intestine together: ________________
2. This organ is found under the liver, it stores bile: ______________________
3. Name the 3 lobes of the liver: ____________, _______________, ______________
4. The organ that is the first major site of chemical digestion: ____________________
5. Eggs, sperm, urine and wastes all empty into this structure: ___________________
6. The small intestine leads to the: ____________________
7. The esophagus leads to the: _______________________

8. Yellowish structures that serve as an energy reserve: ____________________
9. The first part of the small intestine(straight part): _______________________
10. After food passes through the stomach it enters the: ____________________
11. A spider web like membrane that covers the organs: ______________________
12. Regulates the exit of partially digested food from the stomach: ________________
13. The large intestine leads to the __________________
14. Organ found within the mesentery that stores blood: _____________________
15. The largest organ in the body cavity: _____________________
16. A frog does not chew its food. What do the positions of its teeth suggest about how the frog uses them?
17. Using words, trace the path of food through the digestive tract.
18. Using words, trace the path of blood through the circulatory system, starting at the right atrium.
19. What do you think is the function of the nictitating membrane, and why?
20. Which parts of the frog's nervous system can be observed in its abdominal cavity and hind leg?
21. Suppose in a living frog the spinal nerve extending to the leg muscle were cut. What ability would the frog lose? Why?
22. The abdominal cavity of a frog at the end of hibernation season would contain very small fat bodies or none at all. What is the function of the fat bodies?
23. Structures of an animal's body that fit it for its environment are adaptations. How do the frog's powerful hind legs help it to fit into a life both in water and on land?

Label Diagram
Internal Organs



A. ____________________
B. ____________________

C. ____________________
D. ____________________
E. ____________________
F. ____________________
G. ____________________
H. ____________________
I. ____________________
J. ____________________

K. ____________________
L. ____________________
M. ____________________
N. ____________________

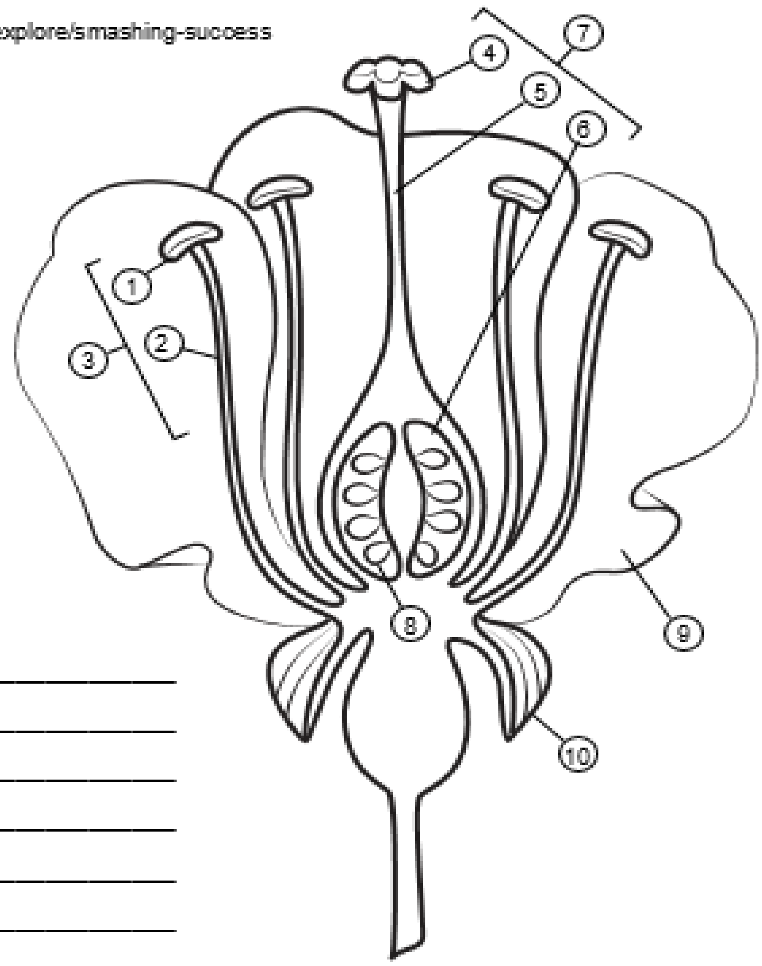
Appendix H: Case 1 Scaffolding Documents

Name: __________Ms. Jeannie_________

Flower Anatomy Activity

The parts of a flower have been labeled.
Your challenge is to write the correct name for each part.

To learn more, visit
http://askabiologist.asu.edu/explore/smashing-success



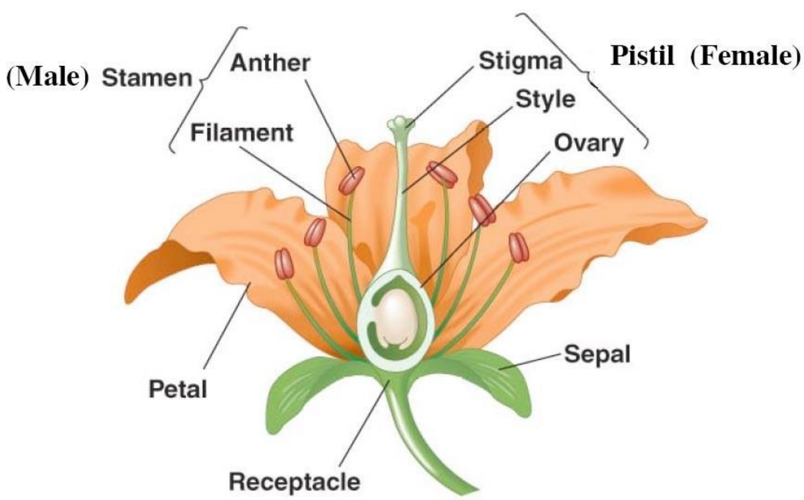
1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

Flower Dissection Lab Activity

Background Information:
Every flower consists of a set of adaptations that help to ensure successful reproduction. For example, flowers often have bright colors, attractive shapes, and pleasing aromas. These traits help them attract insects and other animals that will carry pollen grains from flower to flower. Pollination also occurs by means other than animals carrying the pollen. For some flowering plants, the wind plays an important role in transferring pollen from plant to plant.

The seed-bearing plants that produce flowers are **angiosperms**. The flower produces the seeds, each of which contains a new plant embryo. The parts of the flower are usually found in whorls, or rings. **Petals** are one of the sets of whorls. They attract pollinators. **Sepals** lie outside the petals. They protect the bud.

The reproductive organs, the stamens and pistils, lie inside the petals. A **stamen** is a male reproductive part. It consists of an anther that is held up by a **filament.** The **anther** produces pollen grains. A **pistil** is a female reproductive part. Its top is called the **stigma.** It is sticky to ensure that when pollen grains land on it, they stick to it. The middle supporting structure is the **style,** and the large base is the **ovary,** where the eggs are produced.



Materials:
Flower, Forceps, Magnifying Glass, Glue/Tape, Scalpel/Razor (optional)

Procedure:

1. Locate the outermost layer of flower parts. These are the sepals. Carefully remove the sepals.
    a. Record the number of sepals, attach one, and describe the function in your data table.

2. Identify the petals. These form the next layer of flower parts. Carefully remove each petal. a. Fill in the data table on the next page.
    b. What advantage to the flower are colorful petals?

___

    c. Why are the sepals and petals referred to as "accessory parts" (of the plant)?

___

3. Now locate the stamen. These male flower parts should now be exposed.
    a. Record the number of stamen, attach one, and describe the function in your data table.
    b. What do anthers produce? ___
    c. Name the flower part that elevates the anther. ___ d. Why is it important to elevate the anthers?

___

    e. Describe two different ways that a pollen grain can get to the stigma of a pistil.

___

___

    f. Flowers usually contain more stamen than pistils. Why do you think this is?

___

___

4. The female flower part remains.
    a. Record the number of pistils, attach one, and describe the function in your data table.
    b. Name the flower part that elevates the stigma. ___ c. Why is it important to elevate the stigma?
    d. How does the structure of the stigma aid in pollination?

___

___

    e. Which parts of the flower develop into the seeds? ___
    f. When fertilized, what will the ovary grow into? ___
5. Leaf: Attach a leaf from your plant in the space below.

6. Is the specimen that you brought to school a monocot or dicot? Give multiple reasons to explain how you know this.

____
____
____
____

Data:

Flower Part	Number of	Attach one of each part below.	Description of function
Sepal			
Petal			
Stamen		(Label the anther and filament)	
Pistil/Carpal		(label the stigma, style, ovary)	

Name:______Mr. Stewart________________________

Photosynthesis Virtual Lab

Site 1: Glencoe Photosynthesis Lab Site: bit.ly/pholab
Experiment Question: **"Which colors of the light spectrum are most important for plant growth?"**

1. Make a hypothesis about which color in the visible spectrum causes the most plant growth and which causes the least plant growth.

Plants will grow best with [red / violet / blue / green / orange] light (circle)

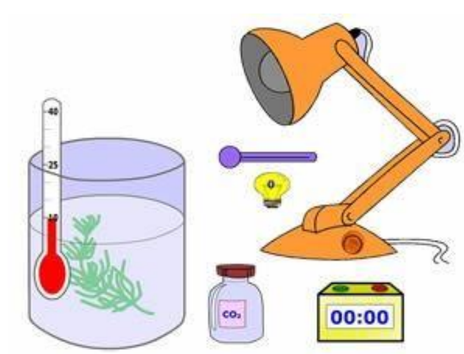
Plants will not grow well with [red / violet / blue / green / orange] light (circle)

2. Collect data by changing the color of light. Test each type of plant and use the ruler to measure the height. Take an average for each plant at each color.

Color	Spinach		Radish		Lettuce	
	Individual	Average	Individual	Average	Individual	Average
Red						
Orange						
Green						
Blue						
Violet						

3. Write your **conclusions** which include an answer to the original question / hypothesis. Your answer should be in a complete sentence.

Site 2: Photolab



http://biol.co/weedsim

This simulation allows you to manipulate many variables. You already observed how light colors will affect the growth of a plant, in this simulation you can directly measure the rate of photosynthesis by counting the number of bubbles of oxygen that are released. Propose hypotheses on how each of these **variables** effect the production of oxygen from a plant. (circle below)

a) Increasing the light intensity will [increase / decrease] rate of photosynthesis.

b) Increasing CO2 levels will [increase / decrease] rate of photosynthesis.

c) Increasing temperature will [increase / decrease] rate of photosynthesis.

I. Question: How Does Light Intensity Affect the Rate of Photosynthesis?

Procedure: The purple slider can be used to change the light levels. You will count the number of bubbles at each level. The timer in the square box can be used to measure 30 seconds.

Light Intensity	0	5	10	15	20	25	30	35	40	45	50
Number of bubbles (30 sec)											

A) Based on the light tests, as you increase the intensity of light, the rate of photosynthesis

[increases / decreases / stays the same].

(circle) B) How do you know?

C) What are the bubbles really showing?

II. Question: How Does Carbon Dioxide Affect the Rate of Photosynthesis?

Procedure: Set the light to its highest intensity (50). Adjust the CO2 levels by clicking on the bottle.

	Full CO2	Half CO2
Number of bubbles (30 sec)		

*Write a conclusion in a complete sentence that describes how the level of CO_2 affects the rate of photosynthesis. *(Use Question 1A to help you write this. It will look similar.)*

III. Question: How Does Temperature Affect the Rate of Photosynthesis?

Create a data table (use the ones above to help you) and input values for at least 3 Temperatures

Use your data to write a conclusion. This should be in a complete sentence.

Appendix I: Case 1 Simulation and Scaffolding Resource Comparison

Inquiry Indicator	Simulation alone	Scaffolding Documents	Lesson Plan	Change in Simulation vs. Scaffolding Documents	Change in Simulation vs. Lesson Plan
Overall Instruction of Level of Inquiry	Exemplary 3.9	Proficient 3.1	Proficient 2.7	-.8 Proficient	-1.2 Proficient
Overall Discourse of Level of Inquiry	Exemplary 3.7	Proficient 2.8	Proficient 2.8	-.9 Proficient	-.9 Proficient
Overall Assessment of Level of Inquiry	Proficient 3.4	Proficient 2.7	Proficient 2.9	-.7 Proficient	-.5 Proficient
Overall Curriculum of Level of Inquiry	Proficient 3.0	Developing 2.2	Developing 2.3	-.8 Developing	-.7 Developing

Appendix J: Case 2 Simulation and Scaffolding Resource Comparison

Inquiry Indicator	Simulation alone	Scaffolding Documents	Lesson Plan	Change in Simulation vs. Scaffolding Documents	Change in Simulation vs. Lesson Plan
Overall Instruction of Level of Inquiry	Developing 2.0	Developing 2.0	Exemplary 3.8	0 Developing	+1.8 Proficient
Overall Discourse of Level of Inquiry	Preinquiry 1.0	Developing 2.0	Proficient 3.0	+1.0 Developing	+2.0 Developing
Overall Assessment of Level of Inquiry	Preinquiry 1.3	Developing 2.0	Proficient 2.8	+.7 Developing	+1.5 Developing
Overall Curriculum of Level of Inquiry	Preinquiry 1.0	Developing 2.0	Proficient 2.6	+1.0 Developing	+1.6 Developing

Appendix K: Case 1 Downloaded Flower Pollination Simulation Worksheet

Name: ________________________ Date: _________________________

Student Exploration: Flower Pollination

Vocabulary: anther, cross-pollination, filament, fruit, ovary, ovules, petal, pistil, pollen, pollen tube, pollination, self-pollination, sepal, stamen, stigma, style

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. How do insects help a plant to reproduce?

____

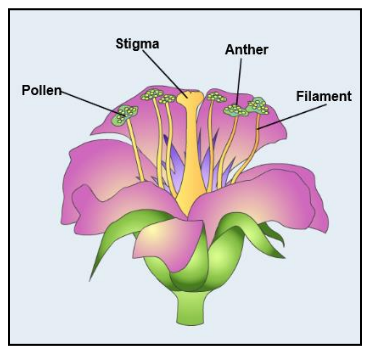
2. Apples, oranges, and watermelons are all examples of **fruits**. How are they all alike?

____

3. Based on your answer to question 2, do you think that a pumpkin is a fruit? How about broccoli? ____

Gizmo Warm-up

Pollination is the transfer of **pollen** grains from the male part of a flower, called the **stamen**, to the female part of a flower, which is called the **pistil**. This fertilizes the female flower and enables it to produce seeds and fruit. In the *Flower Pollination* Gizmo, you will explore how this process works.



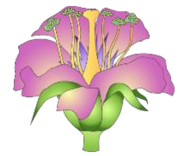
1. On the POLLINATION tab, check that **Self-pollination** is selected. How many flowers do you see? _________

   Notice the different parts of the flower. The **stigma** is a sticky surface at the top of the female pistil. The male **stamen** consists of a long filament and a pollen-producing **anther**.

2. Select **Cross-pollination**. How many flowers do you see now? _________

3. How do you think **cross-pollination** may be different from **self-pollination**?

____

Activity A: Pollination	Get the Gizmo ready: • Select the POLLINATION tab. • Click **Self-pollination**. • Click **Start over**.	

Question: How are self-pollination and cross-pollination the same and how are they different?

1. Observe: Follow the directions in the Gizmo to observe the steps of self-pollination. In your own words describe what happens in each step.

1	
2	
3	
4	
5	

2. Think about it: Read the description of the last step carefully. Why do you think plants surround the seeds with a yummy fruit?

____

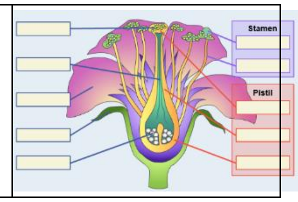
3. Observe: Click **Start over**, then click **Cross-pollination**. Follow the directions to observe the steps of cross-pollination. How is cross-pollination different from self-pollination?

____

4. Extend your thinking: In cross-pollination, pollen grains must get from one flower to another. What are some ways that this might happen? Discuss your answer with your teacher and classmates.

____

____

Activity B: **Flower parts and pollination**	Get the Gizmo ready: • Select the IDENTIFICATION tab. • Click **Start over**. • Check **Show information**.	

Goals: Identify the parts of the flower and describe the function of each.

1. Complete the diagram: Drag the ten listed flower parts to the blanks in the diagram. When a part is labeled correctly, information about the part appears below.

   When your diagram is complete, click the camera icon at upper right to take a snapshot. You can then paste the snapshot into a blank word-processing document.

2. Test yourself: Uncheck **Show information**. For each flower part below, write the letter of the correct description. Use the Gizmo to check your answers.

______	**Anther**	A. A small leaf that protects the flower before it blooms
______	**Filament**	B. They contain pollen
______	**Ovary**	C. Tiny grains that contain sperm cells
______	**Ovules**	D. The male part of the flower
______	**Petal**	E. The part of the pistil between the stigma and the ovary
______	**Pistil**	F. They grow from a pollen grain to an ovule
______	**Pollen**	G. The female part of the flower
______	**Pollen tube**	H. They contain the egg cells and develop into seeds
______	**Sepal**	I. A part of the plant that attracts insects
______	**Stamen**	J. A stalk that supports the anther
______	**Stigma**	K. The sticky top of the pistil
______	**Style**	L. The part of the pistil that contains the ovules

3. Make connections: How might having the anther atop a tall filament make it more likely that plants will be pollinated?

   ____

4. Think and discuss: In some plants, the pistils don't form until a few days after the stamens do. How might this keep a plant from self-pollinating?

   ____