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Concordia University–Portland
College of Education
Doctorate of Education Program

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The Effect of the Directed Case Study Method on the Critical Thinking Skills of High School
Students

Daniel Weaver

Concordia University Portland

College of Education

Dissertation submitted to the Faculty of the College of Education in partial fulfillment of the
requirements for the degree of Doctor in Education in Teacher Leadership

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Abstract

Many teachers struggle to find teaching methods that meet educational goals effectively. One common instructional goal is to emphasize critical thinking. Generally, critical thinking refers to the way individuals approach problems, apply information in new ways, and understand multiple sides to an issue (Willingham, 2007). This quasi-experimental study investigated the effect of the directed case study method on the critical thinking skills of high school students. The directed case study method is an example of case-based teaching, a method that features a relevant story and incorporates objective questions. The study was conducted in a large, semi-urban high school, with 79 9th and 10th grade general biology students. Students were divided into a non-case study group ($n = 17$) and a case study group ($n = 62$). Both groups were given a critical thinking testing instrument at the start of the study, a second version of the instrument at the mid-point of the study, and a third version of the instrument at the end of the study. The scores were analyzed using repeated measures analysis of variance with post-hoc tests. The design of this study offered an alternative to traditional pre and post-tests that are common to education research. In the results of this study, a statistically significant difference was shown between student scores on their first, second, and third attempts at the critical thinking test. There was a statistically significant interaction effect. However, the mean scores of the case study group remained consistent while the scores of the non-case study group decreased over time. Based on these findings, the author suggests that the directed case study method may present a viable, active teaching methodology, but more research is needed.

Keywords: directed case study, critical thinking, case-based teaching, repeated measures

Dedication

To my fellow educators who relentlessly pursue their craft.

To Bill Fiery, who placed the glowing ember in my heart.

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First, I thank the Lord Jesus Christ “in whom are hidden all the treasures of wisdom and knowledge” (Colossians 2:3, New King James Version). Special thanks to my loving wife and family, who sacrificed much, endured patiently, and cheered me on every step along the way. I also wish to thank my Christian brothers and sisters who spurred me on with their wit and wisdom. A special thanks goes to my dissertation committee, and especially Dr. Booker, for chairing my committee and walking with me on this journey.

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Chapter 1: Introduction

Avery, a novice teacher at a public high school, sits at her desk during her planning time. She pours over student data, state and local curricula, budget request forms, and the school calendar to make a single decision. Avery must choose an instructional method that fits her educational goals, learning objectives, curriculum requirements, personal abilities, and teaching philosophy. Juggling all these factors is difficult, especially since different education gurus tout their method as the one that will raise students' standardized test scores. Which method will Avery choose? What factors should influence her decision most?

Each day, educators must select the teaching methodology that best fits their instructional goals. For many educators, one factor influencing their decision is striking a balance between student engagement and available resources. Other concerns include an obligation to cover state and local curricula, and the pressure of standardized testing. These factors will be discussed in the following paragraphs.

Student Engagement

Teachers recognize that active learning strategies engage students, increasing student performance (Connell, Donovan, & Chambers, 2016). Student academic engagement is a term used to describe the relative amount of interest a student shows in learning (Libby, 2004). Appleton, Christenson, and Furlong (2008) argued that student interest is influenced largely by students' motivation to learn. Therefore, use of active learning strategies tends to increase student motivation, and subsequently, student performance (Klegeris & Hurren, 2011). Active learning strategies require students to discover, organize, and communicate information (Kahn, Egbue, Palkie, & Madden, 2015). Despite their benefits, active learning strategies tend to

require more resources than traditional lecture or other teacher-centered strategies. Resources required to implement active learning strategies may include planning time or instructional materials. For example, inquiry-based science labs require some trial and error by students, meaning more materials are consumed in the process. This strain on time and materials creates tension between resource allocation and the desire to maximize students' academic performance.

Second, active learning strategies tend to be more time consuming than lecture-based teaching. Time is spent giving directions, explaining expectations, and allowing students to solve problems. However, instructional time is a valuable commodity amid burgeoning national, state, and local curriculum requirements. Dispensing information in a lecture format is a more efficient way to cover the curriculum than most other teaching methods (Malawi Institute of Education, 2004). Despite some teachers' ability to be compelling speakers, lecturing ranks lowest among teaching methods in terms of student engagement and enjoyment (Connell, Donovan, Chambers, 2015; Makokha & Ongwae, 1997). This conundrum creates a conflict between the teacher's desire to cover content within the instructional time available. Teaching strategies chosen must be efficient and effective.

Curriculum and Standardized Testing

The pressure of high stakes testing adds another dimension to teachers' methodology decision making. In many school districts, a percentage of teacher performance evaluations are determined by student test scores (Murphy, 2017). The emphasis on test scores tempts many educators to "teach to the test" rather than emphasize creativity or critical thinking (Dodge, 2009). This dichotomy pits students' test performance against authentic learning.

The shift to measure student learning by standardized tests has other effects on education. Increasingly, educators and policymakers are driven by local, state, and national standardized

testing requirements in curriculum development and implementation (Morgan, 2016). In part, this is due to pressure to address the academic underperformance of students in the United States relative to other countries. Responding to American students' low international test scores (Programme for International Student Assessment, 2006) and reports including *A Nation at Risk* (Gardner, 1983), legislators in the United States enacted the No Child Left Behind Act (2001) and Every Student Succeeds Act (2015). Both pieces of legislation earmarked funding for scientifically-based research to develop teaching strategies to enhance American students' standardized test results. With increased funding, educational researchers have proposed novel teaching methods, curriculum ideas, and techniques to improve the United States' educational system and raise American students' test scores. However, growth in research-based teaching methods will improve education outcomes for American students only if educators understand the research and implement the new strategies it reveals (Slavin, 2003).

More recently, a holistic approach to education has emerged. In sections of the Every Student Succeeds Act (2015), legislators emphasized that quality education goes beyond test results, and some important qualities of education cannot be measured by standardized tests. This line of reasoning emphasizes the educational importance of disciplines such as art, music and creativity. Proponents of Every Student Succeeds Act (2015) argue for cultivating well-rounded students, stemming from the philosophical position that, beyond preparing students for work, education should inculcate an appreciation of culture (Darrow, 2016). Therefore, many parents and policymakers have come to expect that educators should equip students with skills to pursue diverse interests and hobbies. However, this expectation may create tension for a teacher who desires to incorporate art, music, or creativity into their lesson plans, but feels the stress of standardized testing (Morgan, 2014).

Considering these developments in education policy and practice in the United States, many American teachers are in a predicament. The daily decisions involved in crafting lesson plans require teachers to shop for reliable instructional methods. Teachers must become educated consumers of research, evaluating claims, analyzing results, and inferring if the proposed method fits their educational philosophy (Slavin, 2003). Additionally, teachers must balance considerations of time, planning, resources, and the pressure for students to perform well on standardized tests. Finally, in an iteration of the age-old debate between the art and science of teaching, teachers must weigh the value of a data-driven decision on instruction against an intuitive one (Lindley, 1970). The science of teaching bases decisions on research, while the art of teaching accentuates soft skills such as attitude, rapport, and self-confidence. Therefore, a conflict arises between the value of teachers making data-driven decisions or relying on experience or intuition (Datnow & Hubbard, 2015). Essentially, the question is whether some teaching methods consistently are more effective than others and if so, what the criteria should be used to measure efficacy.

Background, Context, History, and Conceptual Framework for the Problem

In current education policy, practice, and theory in the United States, there is a lack of widespread consensus on the fundamental purpose of education (Labaree, 1997). There is no clear frontrunner among educators' and policymakers' many different goals for American students (Tichnor-Wagnor & Socol, 2015). Should American educators teach students to understand content, cultivate creativity, prepare students to enter workforce, develop students' critical thinking, or something else? Perhaps education should be about all those things and more. This ambiguity allows teachers to incorporate their individual philosophy into the choices they make and the methods they use. Each teacher must weigh carefully their goals and how

they hope to achieve them. The best that any educator can hope for is a teaching method that empirically does what it claims (Slavin, 2009).

Considering the demands placed on teachers, perhaps a single instructional goal is not enough for educators. Teachers must be prepared to tackle several things at once—for example, finding a method that simultaneously covers curriculum content and develops students' critical thinking skills or a method that improves students' reading comprehension as well as mathematics scores. Educators' goals can be varied, but the trend is to focus on skills relevant to the modern workplace, including teamwork, creativity, and critical thinking (Greenstein, 2012)

Most educators agree that one of the goals of education is teaching critical thinking skills (Willingham, 2007). However, critical thinking is a nebulous concept, with different authors using the term with different meanings. Most definitions revolve around thinking habits and the way individuals approach problems. Facione (1990) took a philosophical approach, describing critical thinking skills as a combination of interpretation, analysis, evaluation, inference, explanation and self-regulation. Lai (2011) related that the psychological approach to critical thinking emphasis its holistic nature, rather than a set of skills. Regardless of the approach, critical thinking skills are regarded important for students' success in college and career paths (Conley, 2012). Educators who desire to teach both content and critical thinking can use an active teaching strategy called the directed case study method, which covers content through storytelling, engaging students to take an active role in learning (Pai, 2009). Nevertheless, two questions remain: Does the directed case study method foster growth in students' critical thinking and is there a quantitative way to measure critical thinking?

Statement of the Problem

One problem facing educators is choosing instructional methods that meet their goals. A literature review of the directed case study method did not uncover any convincing empirical support for the method. The literature to date on case studies illuminates some pros and cons of the directed case study method, but yields no empirical data on a link between case studies and students' critical thinking. A gap exists in the literature regarding utilizing case studies at the high school level and quantitative evidence that the directed case study method increases critical thinking. The question driving this study is: Does the directed case study teaching method increase critical thinking skills in 9th and 10th grade biology students? Discovering an answer to this question may provide teachers a clearer indication of the functionality of case studies in the classroom. In addition, answering this question may reveal how teaching methods influence critical thinking skills. Last, the design of this study may be useful for researchers seeking to clarify the utility of teaching methods in the future.

Purpose of the Study

The purpose of this quasi-experimental study was to explore the effects of using the directed case study teaching method on the critical thinking skills of high school biology students. This quantitative study sought to ascertain whether use of directed case studies improved student performance on a critical thinking assessment. The outcomes of this study may be used to inform educators of a specific benefit of the directed case study teaching method. By linking a benefit to a teaching method, this study may help teachers to find the tools necessary to attain their goals as educators. The quantitative research design used in this study may be useful for researchers seeking to establish a clear connection between teaching method and result.

Research Question

This research was designed to answer the following question: Will students taught using the directed case study method have higher scores on a critical thinking assessment compared to students taught using the teacher-centered method?

1. H_{01} : The mean test scores on the critical thinking Assessment One, Two, and Three will be equal regardless of group (that is, there is no main effect for the time factor over three levels).
2. H_{A1} : The mean test scores on the critical Thinking Assessment One, Two, and Three will not be equal regardless of group (that is, there is no main effect for the time factor over three levels).
3. H_{O2} : The mean test scores on the critical thinking assessment of students instructed using directed case studies will be equal to the mean test scores of students instructed using teacher-centered methods (that is, there is a main effect for the group factor over two levels).
4. H_{A2} : The mean test scores on the critical thinking assessment of students instructed using directed case studies will not be equal to the mean test scores of students instructed using teacher-centered methods (that is, there is no main effect for the group factor over two levels).
5. H_{O3} : There is no difference in the mean scores on the critical thinking assessment for any factor level combination (that is, there is no interaction effect).
6. H_{A3} : There is no difference in the mean scores on the critical thinking assessment for any factor level combination (that is, there is no interaction effect).

Rationale, Relevance, and Significance of the Study

This study is significant within the relevant literature for several reasons. First, this study sought to establish a link between the directed case study teaching method and growth in students' critical thinking. Establishing this linkage, as this study sought to do, would make the directed case study a viable option for teachers looking for a methodology that develops students' critical thinking. Second, this study could encourage teachers to try a new teaching method. Regardless of the results of this study, exposure to a new approach to teaching may prompt some teachers to utilize case studies in their classroom. Even teachers who do not want to adopt case-based teaching in its entirety may incorporate case studies in their lessons or assessments to some degree. Third, this study could inspire a change in teaching philosophy. A teacher who has taken a traditional, teacher-centered approach may adopt a more active learning approach because of this study. Even teachers who do not change their classroom practices to incorporate active learning strategies fully may began a gradual transformation. Fourth, researchers could use this study's quasi-experimental design to discover if other teaching methods develop critical thinking skills. This study's methodology could be useful to researchers testing which pedagogies can influence students' critical thinking. Replicating the research design may inspire more research into the strengths and weakness of other teaching methods.

In addition, this study is significant because teachers may use its findings to enhance student performance, refine case-based teaching through implementation, and adopt practical approaches to education. If case-based teaching is shown to be effective and teachers implement case-based teaching (CBT) strategies in classrooms, students will benefit. If school districts adopt CBT, including by providing professional development to support teachers to implement

CBT in classrooms, teachers may begin crafting their own case studies and individualizing CBT. The philosophy of CBT is pragmatic—give students a compelling reason to learn (Herreid, 2005).

Definition of Terms

Active learning. This term is defined as teaching strategies and techniques that require students to be physically and intellectually involved in their own learning. Students plan how to build their background knowledge, choose problems to investigate, and often work cooperatively. Synonymous with student-centered instruction, active learning may include research projects or experiments that require students to take initiative.

Critical thinking. This term is defined as the way humans think about and approach a problem through reasoning, making decisions, and forming judgments (Willingham, 2007). Kuhn (1999) emphasizes that critical thinking involves awareness—knowing facts and knowing the best way to apply those facts to new information. While there is some debate about what critical thinking entails, most researchers agree that it is the application of knowledge, using information in a new or different way, and the ability to see multiple sides of an issue.

Case-based teaching. This term is defined as a teaching technique that uses a story to provide the context for content information. The narrative of the story either provides the background information or frames a compelling problem (Herreid, 2005). The course material can then be applied to the case study.

Teacher-centered instruction. This term is defined as a teaching method where the instructor dispenses the information as fact and shows students how to solve problems. The teacher directs the learning, choosing all the activities (Kain, 2003). Typically, this teaching style includes lessons delivered in lecture format and textbook related assignments.

Assumptions, Delimitations, and Limitations

An assumption in the study was that teacher quality would influence the effect of CBT on students' critical thinking. The assumption was that each teacher participating in the study would present the case studies to the best of their ability. However, teachers' level of ability, area of interest, and rapport with students differ widely. Additionally, teachers in this study were assumed to have the capacity to implement the directed case studies with fidelity to CBT, even without extensive training. Teachers may have incorporated other techniques into their instruction.

One delimitation of this study was the selection of the participants. The participants resulted from the non-random sampling used in the research process. Study participants were restricted to one high school, two grade levels, and one subject area. The high school had approximately 2,000 students and 150 teachers. Only 9th and 10th grade general biology students were included in the study. However, these students were taking other classes throughout the school day during the study. This study did not include honors biology students because these students take an accelerated biology course in 9th grade.

A second delimitation of the study is the type of case used for the CBT. The study compared the effect of directed case studies on students' critical thinking skills with a control group taught using teacher-centered methods. However, other types of case studies exist. For this reason, the effectiveness of CBT in general was beyond the scope of this study. This study focused on students' critical thinking skills rather than overall academic performance or content knowledge. Additionally, using content from other subject areas may provide different results if critical thinking skills are related to domain knowledge (Willingham, 2007).

There are several limitations to be considered. Quasi-experimental designs in education research are fraught with variables that cannot be controlled (Creswell, 2014). Limitations of time and resources impinge the scope, and applicability of this study. For example, obtaining permission from the parents and participants led to a relatively low sample size. Smaller sample sizes reduce the generalizability of the results. Additionally, conducting the study towards the conclusion of an academic calendar year may have introduced confounding variables such as decreased student motivation, pressure from standardized testing, and teachers accelerating the daily pace to meet curricular demands.

Summary

The purpose of this introduction is to provide background and a framework for the remainder of the study. The background included the significance of choosing a teaching methodology that aligns with a teacher's goals. Those goals may be affected and compounded by the demands placed on a teacher from federal, state, local, and philosophical sources. This study's quasi-experimental design was intended to provide quantitative insight into whether the directed case study method could develop students' critical thinking skills.

The framework of this study is as follows. In Chapter 2, the literature on CBT is reviewed, along with descriptions of philosophical, theoretical, and experimental implementation of case studies in teaching. In Chapter 3, the methods of data collection and research design used to answer this study's primary research questions are described. In Chapter 4 results and findings of the critical thinking assessments given in this study are discussed, including evidence of growth in students' critical thinking skills. In Chapter 5, an interpretation of these results is provided, and the implications of this research are discussed.

Chapter 2: The Literature Review

Avery is a 22-year-old novice teacher, teaching at a large, rural, public high school. She began the school year armed with the latest teaching strategies, novel classroom management techniques, and a seemingly unending supply of enthusiasm. Yet, as the school year ends, Avery feels disillusioned. Her students were rowdier than she expected, many of her lessons turned out lackluster, and the force of her enthusiasm was not enough to motivate some of her students to turn in their homework assignments. Avery envied Mr. Carthwright, a veteran teacher who taught in the classroom adjacent to Avery's. Avery noticed that Mr. Carthwright's students sat at their desks quietly during class time, diligently scribbling notes from lectures that Mr. Carthwright could deliver in his sleep. The other neighboring classroom to Avery was taught by Ms. Potswell. Ms. Potswell's students usually were engaged in group projects of some kind, and her classroom seemed so lively. Avery wished that her students had that kind of enthusiasm, but whenever she asked one of Ms. Potswell's students about what they were learning, the students shrugged and never seemed to give a clear answer. To add to Avery's consternation, in the last department meeting, both Mr. Carthwright and Ms. Potswell claimed to have completed the entire curriculum, whereas Avery had to cut out the last unit.

Avery's situation is not uncommon among teachers, and her situation raises some intriguing questions (Shoffner, 2011). What are some of Avery's expectations as a novice teacher? How are Mr. Carthwright's lessons different from Ms. Potswell's lessons? What can Avery learn from the other teachers in her department? What do the other teachers do that Avery should avoid? Is there a way for Avery to cover the content of the course in an interesting way, and yet stay true to her constructivist philosophy of education?

Study Topic

There are no easy answers to those questions: No one teaching method is the silver bullet that guarantees student engagement and scholastic achievement. However, some instructional methods may achieve specific educational goals better than others. The educational goal determines the instructional method that is most appropriate (Chaplin, 2009). Directed case studies are an instructional strategy that allows students to correctly apply content information to real world problems. The narrative of the case study has the purpose of teaching a concept (Montpetit & Kejiura, 2012). Utilizing case studies, like the story of Avery and her dilemma, gives the reader an opportunity to reflect on the story, analyze the characters, apply theories to real world situations, and potentially, to develop critical thinking skills. In short, case studies are an instructional method featuring storytelling for an educational purpose (Herreid, 2005).

Of the wide variety of case study types, directed case studies are relatively easy for teachers to adopt (Herreid, 2005). The directed case method features objective questions, promotes critical thinking, and is conducive to content-rich classes (Cliff & Curtin, 2000). The advantage of using the directed case method for this study is twofold: the relative ease of transition from lectures, and objective scores can be quantitatively analyzed to measure content comprehension. This dissertation examined the potential use of directed case studies as an instructional method in high school science classes to cultivate critical thinking skills. Specifically, this study is intended to investigate quantitatively whether an empirical relationship exists between the use of directed case studies as a teaching method and the development of critical thinking skills in students.

Chapter Two is organized by highlighting thematic concepts in the existing literature on case studies. The introduction sets the stage by describing the context, and the need for

empirical research to tie CBT to critical thinking. The literature is viewed through various themes. First, case studies are a subcategory of PBL, which is an active teaching method. Second, CBT has been developed based on the constructivist framework. Students participate actively in acquiring the knowledge necessary to analyze the problems presented in case studies (Prince & Felder, 2006). Third, using the theoretical perspective of case studies, educators place the responsibility on students to analyze information critically, apply information to real world problems, and develop a systematic approach to problem-solving (Gallucci, 2006). CBT's constructivist approach may facilitate the development of critical thinking skills.

In the fourth topic of Chapter Two, the research and methods used to study the facets of PBL and CBT in this study are reviewed. This section also will include a review of methodological issues in published articles on CBT. In the fifth theme of this literature review, the synthesis of research findings will be elaborated on and previous research critiqued. In the synthesis of research findings, broad themes in the existing literature on case studies will be discussed, and existing research analyzed, including the evidence and claims of research to date on case studies. Chapter Two will be concluded with a summary review of the chapter's major sections.

Context

The focus of this dissertation is the use of the directed case study method within the context of active learning strategies, problem-based learning, and constructivism. Active learning strategies require students to participate intellectually in the learning process by collecting and analyzing information rather than passively listening to a lecturer presenting information (Popil, 2011). Problem-based learning is an example of an active learning strategy. Problem-based learning (PBL) is an umbrella pedagogy that includes instructional methods like

case studies (Hmelo-Silver, 2004). PBL is a constructivist teaching philosophy, whereby teachers use active learning techniques that require students to analyze a problem, investigate relevant information, and collaborate to arrive at a potential solution (Cetin-Dinar, 2015). While CBT utilizes many of the same active learning techniques as PBL, CBT frames the relevant problem in story form. This conceptual framework will be discussed in more detail later in this chapter.

Active learning strategies, like PBL and CBT, foster critical thinking skills in students (Noblitt, Vance, & Depoy-Smith, 2010). Critical thinking skills help students apply science concepts to new situations and are transferrable to other content areas (Lauer, 2005). Critical thinking skills have come to be viewed as a defining characteristic of educated individuals (Hunter, 2015). Facts are easy for anyone to obtain in an information-rich society but analyzing and applying information in unique ways is a marketable skill. The research proposal for this study sought to investigate empirically the effect of CBT on students' critical thinking skills.

Significance

Current knowledge of the effect of case studies on students' critical thinking skills mostly is based on inferences, qualitative observations, and anecdotes. Does the directed case study method have an empirical effect on students' critical thinking skills? To examine this question, first one must consider the relative value of teaching critical thinking skills. The second step is to evaluate if the direct case study method is an effective strategy to improve critical thinking skills. The final step is to use an objective instrument to measure the level of critical thinking.

What is the value of teaching critical thinking skills? One current dilemma in science education is the tension between listing imminently archaic facts on the one end of the instruction spectrum and strictly focusing on the process of applied experimentation on the other

(Hudson & Buckley, 2004; Papacosta, 2008). Proponents of the need for students to develop 21st century skills—such as collaboration, innovation, and problem solving—clamor for educators to focus on developing students’ cognitive proficiencies, while opponents argue that knowledge is the foundation of cognitive function (Kivunja, 2014). Cliff and Curtin (2000) noted that, in prioritizing higher-order thinking skills gained through active learning, educators have less time to teach important content. Nava-Whitehead, Augusto, and Gow (2011) lamented that instructors often try to cover too much content, neglecting the cognitive development of students’ problem-solving skills and critical thinking. Is there a way for educators to build students’ contextual knowledge base through applying content to real world problems?

The dawn of the Information Age brings the clarion call to reevaluate educational goals in light of the changing needs of society (Conley, 2012). The change from the repetitive tasks of an industrial society to the dynamic, flexible learning demanded in an information rich society is daunting for educators (Segers, Dochy, & De Corte, 1999). New educational goals include relevance and critical thinking skills. Kesner, Hofstein, and Ben-Zvi (1997) argued that rapid advances in scientific discoveries warrant science education that is relevant to technology and daily life. Tiwari, Lai, So, and Yuen (2006) submitted that critical thinking should be a prominent goal for modern educators. A student who can recite memorized facts, but is unable to analyze, infer, and demonstrate effective reasoning skills is at a severe disadvantage (Facione & Facione, 1994). Amid changes in the global economy, it is no longer enough for students to possess information—they must be able to apply the information correctly.

Are directed case studies an effective teaching method for improving students’ critical thinking skills? One potential answer to the tension between teaching content or cognitive skills lies in an instructional method that facilitates critical thinking skills while fostering an

understanding of science content. The directed case study method may be an effective strategy for science teachers to help students develop critical thinking skills through content-rich classes. Case studies can be made relevant, interesting, and conducive to developing students' higher-order thinking skills (Cliff & Curtin, 2000). In the paragraphs that follow, the significance of case studies is discussed, including case studies' relevance to students, interest to students, and capacity to develop higher-order thinking skills in students.

By demonstrating appropriate real-world application of scientific concepts, educators can use case studies to highlight the relevance of science content to students who view science class as a string of unrelated and unusable facts. For example, Dinan (2002) discovered that use of relevant case study topics led to higher student evaluation scores of his non-science majors' chemistry course. Brickman (2006) recommended using relevant case studies in large introductory level biology courses. Although an essential element of effective CBT (Fossey & Crow, 2011), relevance is difficult to define. Wolter, Lundeberg, and Bergland (2013) argued that relevant science lessons address students' interest, students' curiosity, or highlight practical applications of science content. Camil (2006) found that relevant lessons motivated students to apply science concepts to their everyday lives. The focal point of the literature to date on CBT is the effect of relevant case studies on student motivation.

Students find intrinsic motivation in lessons they perceive as relevant (Montpetit & Kajiura, 2012). Pedersen (2003) noted that relevant case studies activate students' personal interest, igniting their intrinsic motivation. Intrinsic motivation is fueled by curiosity—as Wolter, Lundeberg and Bergland (2013) observed, students' interest in science directly relates to personal curiosity and interest. The benefit of learning goes beyond higher test scores—rather, meaningful learning stimulates students' intrinsic motivation and curiosity, developing lifelong

learners (Nava-Whitehead, Augusto, & Gow, 2011). Effective case stories should be relevant to class content while sparking students' curiosity.

Another way case studies may improve learning is by sparking students' interest in science. Herreid, Prud'homme-Genereux, Schiller, Herreid, and Wright (2016) reported that the top two criteria instructors use to choose a case study are the quality of the story and students' interest level. Camil (2006) described case studies as a method whereby educators encourage students to examine science issues by applying concepts to real world problems. In his autobiographical description of his students' learning experiences, Camil (2006) demonstrated how educators can spark students' interest in science, reporting that his students were hooked by the problem or story presented in his case studies. Wolter, Lundeberg, and Bergland (2013) described their experience utilizing case studies in science classes. The authors found that some students continued to explore the case study after the assignment was over. Arguably, these students were motivated by their compelling interest in the case study in addition to their course grade. So immersed were the students in the content that that they continued to participate after the course concluded. Likewise, Montpetit, and Kajiura (2012) observed that educators can use case studies to stimulate student interest and engagement through an interactive approach to presenting science material. Bilica (2004) argued that case studies pique student interest in science. Use of case studies can increase students' interest in science through compelling stories that bring content to life.

In addition, use of the directed case study method may improve students' critical thinking skills. The problem lies in attributing quantifiable improvements in critical thinking to an instructional method. As described in the relevant literature, researchers have used metrics to measure critical thinking skill development. Kamin, O'Sullivan, Younger, and Detering (2009)

developed a qualitative coding protocol to evaluate evidence of critical thinking during group discussions. Sendag (2009) used the Watson Glaser Critical Thinking Appraisal to compare the effect of an online PBL course on students' critical thinking skills with a traditionally taught course. Facione and Facione (1994) mentioned two other critical thinking skill tests: The Cornell Critical Thinking Test and the Ennis-Weir Critical Thinking Essay Test. They advocate for the California Critical Thinking Skills Test, designed to evaluate quantitatively the effectiveness of an instructional method to develop critical thinking skills in any content area (Facione & Facione, 1994). However, critical thinking tests are not content specific, raising the question of whether critical thinking skills are transferable to problems in different content areas.

Perkins and Salomon (1989) addressed this issue by arguing that people with strong critical thinking skills utilize a wide knowledge base and general cognitive skills together to solve novel problems. The implication for educators is to develop methods that teach students to apply problem solving skills to a domain-specific knowledge base (Perkins & Salmon, 1989). Directed case studies, which tend to motivate students to construct the knowledge base and problem-solving skills needed to tackle real world problems (Kunselman & Johnson, 2004), may be one such method. Using the directed case study method may help teachers to facilitate critical thinking skill development in students.

Statement of the Problem

Science education in the United States is facing mounting pressures to evolve (Darling-Hammond, 2010). One source of pressure is the perception that the United States lags behind other developed nations in math, science, and reading literacy (Tucker, 2012). International indicators reveal that students in the United States rank 23rd in science (Program for International Student Assessment, 2012). Darling-Hammond (2010) asserted that the stagnating

state of science education in the United States no longer meets workforce demands for scientific and technological innovation, creating a technological deficit compared to other nations. Tucker (2012) lamented that, following enormous success in the 20th century, stakeholders in the American educational system have grown complacent. Many American students share this complacency, feeling entitled to good jobs and a high standard of living (Tucker, 2012). However, Americans' current standard of living is not assured in the future, since the United States no longer boasts the best education system in the world (Stewart, 2012).

In addition, the American job market is evolving faster than stakeholders in the educational system can keep up. Conley (2012) argued the futility of teaching job-specific skills to students, instead proposing a focus on cognitive skills that transcend specific occupations. Conley (2012) asserted that the focus of education should be on learning the skills necessary to continue learning, because modern workers change jobs often: millennial Americans switch jobs at least four times by age 32 (Long, 2016). Therefore, Wiley, Wyatt, and Camara (2010) insisted that habits of mind, like problem solving, critical thinking, and inquisitiveness are more important for career success than a job-related skill set.

Sensing this need for change, education watchdogs in the United States have encouraged policymakers to update curriculum science standards. Between 2012 and 2016, less than 38% of high school students who took the ACT met the college readiness benchmark in science (ACT, 2016). Between 2009 and 2015, the scores of high school seniors on the National Assessment of Educational Progress science test remained unchanged, with 22% of students achieving results at or above proficient (The Nation's Report Card, 2015). Science standards in the United States have not changed significantly in over 20 years, despite rapid changes in technology in this time (Next Generation Science Standards, 2017). The Partnership for 21st Century Skills, Common

Core State Standards, American Association of Colleges and Universities, National Education and Technology Standards, and Next Generation Science Standards have proposed updating science standards in the United States to reflect marketable 21st century skills. Yet, most science teachers remain entrenched in traditional, passive teaching methods (Beers, 2005). Might pedagogical changes reignite general interest in science, enhance science literacy, and improve science education in the United States?

Critical thinking skills are essential for success in both the college and career arenas (Conley, 2012). Are secondary science teachers in the United States utilizing methodologies that cultivate students' critical thinking skills? Is the directed case study method an effective pedagogy for developing critical thinking skills in high school science students? Can the development of students' critical thinking skills over time be quantified in a course using case-based instructional techniques? In this study, the effectiveness of the directed case study method in facilitating the development of critical thinking skills in secondary science students was examined. The purpose of this study was to investigate empirically the potential benefits of utilizing directed case studies as a method of classroom instruction by measuring students' critical thinking skills over time utilizing a critical thinking testing instrument.

Case studies can be incorporated into science curricula to varying degrees and through a variety of methods. Directed case studies can be used to demonstrate the relevance of scientific facts, spark student interest, and develop high-order thinking skills without compromising efficiency. By developing critical thinking skills, implementing case studies in science classes may equip students to apply science concepts to real world problems, a desirable 21st century skill.

Conceptual Framework

Efforts to convince science teachers in the United States to adopt new methodologies may face an inertia problem. Instructors want to know if the investment of time and effort to overhaul lessons will pay dividends (Albanese & Mitchell, 1993; Glew, 2002; Lundeburg & Yadav, 2006). However, empirical evidence of pedagogical effectiveness to facilitate 21st century skills emerges slowly (Bilica, 2004). Furthermore, a philosophical shift is needed among educators, from transmitting knowledge to students efficiently via lectures to student-centered, inductive practices like PBL or CBT (Prince & Felder, 2006).

Active, student-centered lessons are a hallmark of constructivism, an education theory whose proponents focus on channeling students' prior knowledge toward the application of science concepts to novel problems (Prince & Felder, 2006). Constructivism aligns closely with CBT and PBL, because the onus is on the students to use critical thinking, analysis, and problem-solving to learn and apply the course content (Tiwari & So, 2006). CBT methods are a subcategory of PBL, an instructional method whereby educators use dilemmas designed to engage students and stimulate thinking (Woody, Albrecht, Hines, & Hodgson, 1999). PBL and CBT require students to engage actively in applying information to relevant problems.

Hunter (2015) outlined the basic principles of PBL: start with an ill-defined problem that students analyze through prior knowledge. Next, students identify knowledge gaps and research potential solutions. Finally, students discuss the pros and cons of potential solutions, before submitting a final answer. Utilizing cooperative learning techniques can give PBL and CBT a social constructivist slant. CBT follows a similar process but differs slightly from PBL—in the case-based method, educators use the power of storytelling to relay the problem to students

(Herreid, Prud-homme-Genereux, Schiller, Herreid, & Wright, 2016). The purpose of this process is to teach students a systematic approach to problem-solving.

Case studies present real world problems in story form and can be a useful tool to illustrate the application of science concepts to real world scenarios (Herreid, 2005; Montpetit & Kejiura, 2012). Utilizing case studies gives students an opportunity to construct knowledge by analyzing characters, applying theories, and developing critical thinking skills (Popil, 2010). In CBT, typically students work in cooperative groups to identify problem(s) and evaluate potential solution(s) to solve the dilemma illustrated by the case study.

In summary, constructivism is a philosophical framework from which active, student-centered teaching strategies like PBL or CBT have been developed. Chaplin (2009) wrote: “A growing body of research indicates that inductive teaching and learning methods (such as case studies, problem, guided instruction, discovery projects or presentations by groups) produce more positive learning gains in science classes than traditional lecture methods” (p. 72). By working together in cooperative teams, utilizing a systematic process to discover solutions to real world problems, students demonstrate active involvement with lesson content. In contrast, students listening passively to a lecture may or may not be listening (Connell, Donovan, & Chambers, 2016). In their survey of educators who used CBT to some degree, Herreid et al., (2011) found that educators’ main reason for using CBT was to increase student engagement and active learning.

Theoretical Lens

Constructivist theory is compatible with inductive teaching because in both methods, educators emphasize the activation of students’ prior knowledge, importance of investigating problems actively, collaborating with others, and experimenting (Qarareh, 2016). Applying

constructivist learning theory to the problems facing science education may alleviate some pressures facing educators. First, liberated from the task of covering a burgeoning curriculum, teachers may instead direct their energies toward teaching students how to become scientific thinkers, actively engaged in learning (Nava-Whitehead, Augusto, & Gow, 2011). Second, science teachers may employ methods that improve students' retention and application of scientific concepts (Tiwari & So, 2006). Finally, exposure to meaningful context may motivate students to pursue a line of scientific inquiry in a systematic and analytical way (Maudsley & Strivens, 2000). The theory is to equip students with the intellectual tools necessary to follow their own lines of inquiry.

As an instructional method, teachers can use CBT to satisfy the demands of content-heavy classes, while engaging students actively (Camill, 2006). Through use of active learning strategies, like PBL and CBT, teachers integrate critical thinking without sacrificing course content (Kek & Huijser, 2011). One criticism leveled at PBL is that insufficient research may lead to gaps in students' knowledge of core content (Glew, 2002). Constructivist educators encourage students to research reliable sources to fill in knowledge gaps (Qarareh, 2016). However, Beers (2005) concluded that students in constructivist, PBL-designed classes demonstrated equivalent content knowledge when compared to students taught with traditional methods. Beers' (2005) finding implied that educators should consider factors other than content when deciding on classroom pedagogy, such as developing critical thinking skills.

Hudson and Buckley (2004) claimed that case studies provide a context that helps students retain knowledge for longer periods of time when compared to other methods. Constructivist theory emphasizes meaningful context for content and social negotiation to collaboratively pursue lines of inquiry (Cetin-Dinar, 2015). Providing an authentic framework

for science material, coupled with the benefits of intentional social interaction leads to deep understanding and longer retention of learned information (Segers, Dochy, & De Corte, 1999). Case studies can provide the framework that helps to answer the age-old question asked by students, “why do we need to know this?” (Wolter, Lundeburg, & Bergland, 2013). Therefore, contextualizing problems not only aids retention, but also increases motivation.

The stories and mysteries found in case studies can also intrinsically motivate students to scientifically investigate real-world problems (Wolter, et al., 2013). Pedersen (2003) observed that active learning strategies encourage intrinsic motivation in a variety of students. The active learning of relevant content in a constructivist classroom is related to increased student motivation (Cetin-Dindar, 2015). Interestingly, academically struggling students who are engaged actively in learning and discovery tend to show greater enthusiasm toward learning when compared to students in traditional classes (Pai, Benning, Woods, McGinnis, Chu, Netherton, & Bauerle, 2010). The skills students develop through constructivist teaching methods create a natural segue toward motivating lifelong learners (Prince & Felder, 2006). The first step is to capture the students’ imagination through mystery, the next is to empower them to solve it.

To review, constructivist theory proposes that students build new knowledge through real world experiences (Prince & Felder, 2006). Educators who adopt a constructivist teaching philosophy in science focus on at least three points of emphasis: teach students how to critically build their own knowledge base (rather than giving the facts), provide a context to facilitate knowledge retention; and cultivate intrinsic motivation through active learning (Gallucci, 2006). Students in a constructivist classroom are engaged in systematic problem solving. This may explain why PBL or CBT facilitate critical thinking skills (Schmidt, Van Der Molen, Te Winkel,

& Wijnen, 2009). Their critical thinking is cultivated through applying facts to real world problems.

Review of Research Literature

The Case-based teaching research review begins with a short historical overview of the origins and spread CBT. Specifically, the directed case study is highlighted because of its adaptability and relative ease of implementation (Herreid, 2005). However, there are some obstacles to implementing CBT both at the programmatic level (Glew, 2002) and the personal level (Dochy et al., 2003). While implementation issues seem to moderate the potential impact of CBT, the potential benefits of CBT are well documented. These benefits include improving students' ability to apply concepts and developing CT skills (Schmidt, 2009).

A Short History of CBT

Case-based teaching first emerged as a teaching strategy at Harvard's law and business schools and was pioneered in medical school curricula at McMaster University in Canada (Fosset & Crow, 2011; Herreid, 2005). From medical schools, CBT and PBL trickled to upper level undergraduate science classrooms for courses like anatomy and physiology (Albanese & Mitchell, 1993). More recently, undergraduate science classes, non-science major classes, and even secondary school teachers have started integrating CBT as an instructional method (Herreid, 2005). Teaching using cases studies is a time-tested tradition.

One of the reasons for the spread of case studies in the classroom is that case studies can be tailored to specific educational goals (Herreid, Schiller, Herreid, & Wright, 2011; Montpetit & Kajiura, 2012). When the educational goals are depth of understanding and critical thinking skills, the directed case study method is an appropriate approach (Herreid, 2005). Directed case studies are comprised of a story related to a specific topic coupled with reflective questions that

emphasize facts, understanding, and application. The National Center for Case Study Teaching in Science Foundation website (2017) describes the directed case study method to augment a student's conceptual understanding. This style of case study can be modified to fit any content topic.

Examples of the directed case study method in college courses are found in the literature. Cliff and Wright (1996) utilized specific objective questions in a directed case study for review, remediation, and application of course content. The directed case study method is conducive to courses like human anatomy and physiology because of the content-rich nature and importance of the correct clinical diagnosis. Additionally, Woody et al. (1999) found the directed case study method effective in teaching students content and developing their critical thinking skills.

Obstacles to Implementing CBT

There are some significant obstacles that slow the proliferation of CBT (Herreid, 2011). The promising features of CBT are developing critical thinking skills, learning science content in context, improving communication skills, facilitating active learning, and increasing test scores. However, one obstacle is that much of the supporting evidence is descriptive or correlational derived from surveys about student preferences (Bilica, 2004; Chaplin, 2009; Lundeberg & Yadav, 2006). Affective studies add insights into classroom dynamics, but offer little empirical evidence exists that support the claims of CBT proponents (Kesner, Hofstein & Ben-Zvi, 1997). More empirical evidence is needed before CBT becomes widely accepted.

Another major obstacle to CBT is the instructor's ability to properly implement the strategy (Dochy et al., 2003). Case studies are implemented by science educators to different degrees, for different reasons, and utilizing a variety of techniques (Schmidt, et al., 2009). Poor

implementation may adversely affect the results of CBT (Glew, 2002). Therefore, an accurate evaluation of the efficacy of CBT relies heavily on the integrity of the implementation of CBT.

Benefits of CBT

The literature review revealed several potential benefits of CBT. Case-based teaching methods and PBL are frequently compared to traditional pedagogical methods in the literature. The results indicate similar student achievement on assessments in knowledge acquisition and recall, but students in CBT classes tend to demonstrate superior understanding and application skills (Albanese & Mitchell, 1993; Capon and Kuhn, 2004; Dochy, Segers, Van den Bossche, & Gijbels, 2003). Deeper understanding of content and the ability to apply information to new and different problems are characteristics of critical thinking skills (Schmidt, 2009). For example, students in a PBL class scored higher than students in a lecture class on comprehension level test questions and analysis level test questions (Antepohl and Herzig, 1999). Sendag and Odabsi (2009) discovered that the PBL format significantly increased the critical thinking skills of university students. The potential benefit of CBT and PBL is teaching students critical thinking skills without eliminating any course content (Lauer, 2005). CBT is a strategy that facilitates comprehension without compromising content.

Arguably, improving critical thinking skills is the most significant feature of CBT (Beers, 2005). The improved learning and higher order thinking skills are manifested in several ways. First, Wolter et al. (2013) concluded that case studies help students demonstrate critical thinking skills through deeper conceptual understanding and improved exam scores. Second, case studies benefit students by improving the skills necessary for applying research. Montpetit, and Kajiura (2012) note that students needed to use critical thinking skills to explain and interpret case studies. Camil (2006) also found evidence of improved higher order thinking after he

implemented case studies. Kunselman and Johnson (2004) asserted that the active learning of CBT facilitates problem-solving and critical reasoning skills in students. Third, critical reasoning is a skill that transcends subject matter. Grunwald and Hartman (2010) identified the transferability of critical thinking skills to other science topics as one of the features of teaching with case studies. Kek and Huijser (2011) advocated for the deliberate instruction of critical thinking skills using PBL. However, Hmelo-Silver (2004) observed that few empirical studies, especially linking the development of critical thinking skills directly to CBT exist in the literature.

Case Studies and Critical Thinking

Despite the references to critical thinking skills throughout the literature, the definition of the term remains elusive. Herreid et al. (2016) found that teachers consider critical thinking to be the most important feature of case studies, even though the term was left to their individual interpretations. Kek and Huijser (2011) summarized a variety of historical definitions by observing that critical thinking is the ability to analyze information, recognize and use logical reasoning to synthesize and evaluate the information, and to apply the information correctly in novel ways. These three characteristics of critical thinking can be used to systematically approach case study problems: clearly identify the problem, analyze the data while focusing on inferences or assumptions, and evaluate the possible solutions to make a recommended course of action (Flynn & Klein, 2001). This approach to problem-solving raises the question of whether critical thinking can be taught.

Herreid (2004) used the term “habits of mind” to describe traits that characterize critical thinkers: problem-solving skills, a healthy sense of skepticism, and the ability to handle dichotomies. Herreid (2004) noted that students can develop those traits if modelled by

instructors. Maudsely and Strivens (2000) went a step further by suggesting that the critical thinking habits should be actively taught alongside the course content, because students can become better critical thinkers. Lauer (2005) provided a few examples of daily incorporating critical thinking into the classroom by emphasizing higher-order thinking questions, inquiry-based laboratory assignments and providing thoughtful feedback. Instructors who specifically emphasize metacognitive thought processes can help students develop critical thinking. Tiwari et al. (2006) concluded that active learning strategies, like PBL and CBT, facilitate an increase in the development of critical thinking skills among students because active learning strategies are conducive to critical thinking thought processes.

To summarize, the literature review recounted the origin of case studies in medical and business schools but gradually migrating to other academic disciplines as well as secondary schools. The spread of CBT and PBL is expedited by the benefits of active learning and the opportunity to develop critical thinking skills but inhibited by some significant obstacles. The obstacles facing CBT and PBL include lack of empirical evidence to support some of the claims made by proponents of CBT and PBL, and improper implementation by educators. Nevertheless, PBL and CBT are active learning strategies that can be used by educators to help students develop critical thinking.

Review of Methodological Literature and Methodological Issues

The research investigating CBT and PBL fall into three categories: qualitative, quantitative, and mixed method designs. Most of the literature is split between qualitative descriptive studies and quantitative correlation studies. The literature showed significantly fewer studies that use mixed-methods or quasi-experimental designs, and even fewer using controlled experiments (Hmelo-Silver, 2004; Yadav, Lundeberg, DeSchryver, Dirkin, Schiller, Maier,

Herreid, 2007). Much of the research focused on post-secondary students, especially medical students, where PBL is common (Hmelo-Silver, 2004). This dissertation intends to fill a gap in the literature by using a quasi-experimental approach.

Qualitative Studies and Qualitative Design Issues

Qualitative studies highlight the value or meaning that individuals assign to something (Creswell, 2014). One trend in CBT research on the qualitative side of the research spectrum is to publish a case study with teaching notes and an account of the instructor's experience (Brickman, 2006; Cliff & Curtin, 2000; Cliff & Wright, 2005; Gallucci, 2006; Hager, 2004; Krauss, Salame, & Goodwyn, 2010). The instructor publishes the paper using a technique like case study research. The case study research method is a technique that investigates an individual or event as a model example of a phenomena (Creswell, 2014). The authors may annotate the lesson with a narrative, instructional ideas and implementation insights. The following are summary examples of this technique.

One example by Cliff and Wright (2005) described a directed case study to aid student comprehension of respiratory physiology. The paper includes the learning objectives, handouts, and classroom procedures to implement the case study. In another example Hager (2004), put together a case study that focuses on the scientific method. The paper details the case study story, highlights key discussion points, lists questions for research, encourages students to replicate the experiment, and advises instructors with classroom management techniques. Brickman (2006) related her experiences with an example directed case study in a large undergraduate Biology class. The paper outlines a story revolving around DNA fingerprinting, learning objectives, data tables, review questions, advice for groups, and suggestions for a wrap up activity.

Another qualitative trend is for authors to relate their experiences with case studies or information about case studies. For example, Montpetit, and Kajiura (2012) recounted their experiences implementing case studies into a college curriculum offering their unique perspectives and adaptations they used to personalize the approach. Camill (2006) shared his experience integrating case studies into a portfolio of active learning techniques. Herreid (2005) described several case study methods, popular grouping techniques, and some of the common pitfalls.

A third trend is to publish a review of the CBT or PBL literature. Popil (2010) maintained that case studies increase critical thinking in nursing students and uses published literature to support that conclusion. Lundeberg and Yadav (2006) examined the research methods to encourage more experimental or quasi-experimental research for CBT. Finally, Hunter (2015) argued that the literature supports using active learning strategies, like PBL or CBT, when anchored in relevant, real-life scenarios.

Qualitative studies offer a unique and insightful perspective into education. Liston, Whitcomb, and Borko (2007) observed that qualitative data can enrich education studies by incorporating the human elements of teacher and student interaction. Furthermore, qualitative research studies can focus on valuable aspects of an educational experience such as socialization, and motivation. The qualitative research approach to CBT include publications relating experiences in a case study fashion, relating personal experiences, and researching the literature to write an informative article.

Quantitative: Descriptive and Correlational Studies and Issues

Quantitative research focuses on numerical data to discover the relationships between variables and can be categorized as experimental and non-experimental (Creswell, 2014). Non-

experimental studies use surveys, assessments or other tools to either describe phenomena or show a potential correlation between two variables. The descriptive studies of CBT and PBL are survey-based and focus on student or teacher perceptions (Bilica, 2004; Chaplin, 2009; Lundeberg & Yadav 2006). The surveys range from how teachers chose to use case studies, to asking if students enjoyed the case study method (Camill, 2006; Herreid, et al., 2011).

Instructor surveys can probe the teaching experience and circumstances that influenced the use of case studies as well as collect demographic data. Herreid (2011) used survey methods to ascertain how and why teachers are using case studies in their classrooms. The results showed that most use the interrupted case study method. Kesner, Hofstein, and Ben-Zvi (1997) determined that both teachers and students enjoyed CBT because the relevance of case studies helped to spark interest. Yadav et al., (2007) found that teachers perceived CBT to be an effective method for building critical thinking skills in students, despite the challenges of increased lesson preparation time. Finally, a survey of pre-service teachers signified their interest in CBT regardless of their individual learning styles (Beck, 2007). These types of surveys are helpful because they provide insight into teachers' experiences and perception of CBT.

Student surveys are typically distributed immediately after a case-based unit or as part of the end of course evaluation. The results tend to focus on student enjoyment, relevance and the resulting increase in student motivation. Woody et al., (1999) surveyed nursing students who reported case studies were enjoyable and helpful. In a similar study, Hudson and Buckley (2004) found the students thought CBT built confidence as they prepared for a medical career. Klegeris and Hurren (2011) discovered attendance was better with case-based instruction and students had a positive experience. When non-science majors were surveyed about the use of case studies in an introductory chemistry class, the students indicated their appreciation for CBT (Dinan, 2004).

Flynn and Klein (2001) focused on student attitudes toward group discussions during a PBL and found students had a positive disposition toward CBT. In a survey administered by Nava-Whitehead et al., (2011) the students reported a positive reaction to an inter-disciplinary case study experience. Even academically struggling students indicated CBT is enjoyable (Pai, et al., 2010). These surveys provide a picture of CBT from students' point of view.

When student enjoyment is coupled with relevant content, student motivation appears to increase. Students who participated in Kunselman and Johnson's (2004) end of the course survey indicated the case study approach was an excellent teaching method because of the group discussions, active learning style, and relevance to real world situations. Survey results also indicated that relevant case-based lessons that demand application of knowledge can foster intrinsic motivation (Pedersen, 2003, Cetin-Dindar, 2016). A course evaluation by Wolter et al., (2013) concurred with the conclusion that the relevance of CBT can spark student curiosity and motivation.

To summarize, descriptive and correlational research studies dominate the literature on CBT and PBL with survey research methods being more commonly used with teachers and students. Both groups generally have positive attitudes toward CBT. While noteworthy, these attitudes are an indirect method of measuring the cognitive effectiveness of the strategy. Assessments may offer a more direct measure of effectiveness, although assessments are far from a perfect measurement tool (Liston, et al., 2007). A few subjective assessments add to the burgeoning body of research, but indirect research designs only provide a partial picture of the evidence that could support CBT. A diagnostic assessment of the correlation between critical thinking skills and CBT would be a more direct approach.

Quantitative Methods: Quasi-experimental and Experimental Designs and Issues

Experimental research specifically relates one cause to an effect by eliminating as many variables as possible (Creswell, 2014). True experiments are difficult in secondary education because of ethical concerns associated with randomization and withholding educational interventions (Cohen, Manion, & Morrison, 2011). Consequently, quasi-experimental designs are more common because of the non-randomization of groups or a single-subject design (Creswell, 2014). Quasi-experiments become the pragmatic alternative to true experiments in educational research.

There are other obstacles that prevent researchers from conducting experimental studies on the effects of teaching strategies. One is the ability to account for all of the extraneous variables. Researchers may try to control variables by randomization (e.g. instructors, participants, and methods) and statistically accounting for variation in student demographics. Another obstacle is that PBL and CBT incorporate other active teaching strategies making isolating a single variable difficult (Katinka, et al., 2003). A third difficulty is the implementation of the teaching method (Cliff & Wright, 1999). Instructors may interpret a wide degree of implementation as CBT.

Quasi-experimental designs often use a pre-test and post-test to measure improvement. A pre-test and post-test design can also be used with survey data and comparing content test scores (Dinan, 2002; Kunselman & Johnson, 2004; Pedersen, 2003). Few studies used a control group with pre/post-test designs. The presence of a control group minimizes the effect of confounding variables and increases reliability (Slavin, 2003). Lundeberg and Yadav (2006) pointed out several flaws in quasi-experimental designs utilizing standardized pre/post-tests including

insufficient process data, confounding variables, inconsistent testing methods, and not aligning tests with research objectives. The following paragraph elaborates on each of these design flaws.

First, insufficient process data is a problem where the pretest and posttest results do not clearly indicate a direct correlation to the teaching method. Second, research designs that do not account for confounding variables are weakened because alternative explanations may have a great influence on the results (Lundeberg & Yadav, 2006). Third, teacher enthusiasm, novelty of the method, and ability to accurately implement the method may all contribute to the success or failure of the lesson. Fourth, inconsistent testing methods include practices where the teaching is focused on higher order thinking, but the assessment consists of multiple-choice lower order recall questions (Herreid, 2015). Finally, the assessment needs to align with the research objectives; if the researcher is measuring the development of critical thinking, one case study may not be enough.

Occasionally, researchers used a quasi-experimental design to collect data such as test scores evaluating content knowledge (Antepohl & Herzig, 1999; Barak, Ben-Chaim, & Zoller, 2007; Capon & Kuhn, 2004; Prince, van Mameren, Hylkema, Drukker, Scherpbier, & van der Vleuten, 2003). However, the type of test questions asked should align with the teaching method (Herreid, 2015). Testing higher level thinking skills requires questions from the same domain (Segers, Dochy, & De Corte, 1999). Testing in a CBT course should include questions in a case study format.

A major problem with the use of test scores is the assumption that they are an accurate reflection of learning. Liston et al., (2007) called attention to the tenuous link between standardized test scores and student learning. Other factors often influence students' standardized test scores such as nutrition, sleep, motivation, and illness. Evidence-based research is beginning

to drive changes in educational practices (Slavin, 2003). Despite the difficulties that are inherent in experimental designs researching CBT, more evidence-based research is worthwhile (Capon & Kuhn, 2004). Unfortunately, the claims found throughout the literature that CBT leads to increased critical thinking skills does not appear to be substantiated by significant amounts of experimental data.

Qualitative research methods were more prevalent in educational research journals around the turn of the century (Hsu, 2005). While qualitative research offers unique insights, and is appropriate in certain circumstances, some research questions are best answered with a quantitative research approach. One of the most common quasi-experimental quantitative designs in education research involves a pretest and a posttest (Dugard & Todman, 1995). The design features a comparison between a baseline score and a post treatment score. The straightforwardness of the design and the relatively simple *t*-test analysis is appealing to researchers desiring to compare mean scores on an assessment. However, researchers should understand the strengths and weaknesses of a variety of study designs, in order to choose the optimal design for their inquiry (Ellis, 1999). Researchers should choose a design based on the type of inquiry, not familiarity, as postulated by *The Law of the Instrument* (Kaplan, 1964; Maslow, 1966).

A repeated measures design also compares mean scores over time. The difference between a pretest/posttest design and repeated measures design is that the participants provide additional data points for analysis with a repeated measures design (Ellis, 1999). The additional data points can generate a more detailed picture of the relationship between the variables (Creswell, 2014). A repeated measures analysis of variance (ANOVA) will indicate if any statistically significant difference exists between data points, and post hoc tests can pinpoint

specifically where those differences are (Laerd Statistics, 2015). No quantitative research studies were found that used a repeated measures methodology to test the efficacy of CBT or PBL. One of the purposes of this research study is to augment the quantitative research on CBT while introducing a repeated measures research design. The repeated measures design may offer insights into the effectiveness of any teaching strategy.

To summarize, experimental research provides a different kind of insight into the effectiveness of CBT. Non-experimental designs that utilize surveys show the attitudes and perceptions teachers and students have toward CBT. However, attitudes and perceptions are only part of the picture. An additional part of the picture is provided by the numerical data found in experimental studies. True experimental studies are difficult to conduct, but quasi-experimental studies indicate that CBT increases students' knowledge, comprehension, and ability to apply information.

Mixed-Methods: Mixed Method Designs and Issues

Researchers also use mixed-method designs, which combine the analysis of survey and test data with the insights of the participants (Pedersen, 2003; Tiwari, Lai, So & Yuen, 2006). Flynn and Klein (2001) used test data from an experimental study with open-ended survey items designed to ascertain the attitudes of students toward case-based teaching. Another example is a study by Price, van Mameren, Hylkema, Drukker, Scherpbier & van der Vleuten, (2003) who used both contextualized and non-contextualized test items in conjunction with a questionnaire to research the possible correlation between PBL and content knowledge. Mixed method research in the literature offers the potential of empirical evidence coupled with student attitudes or valuable observations borne from experiences. Qualitative data collected in a mixed method

design can be used to analyze a correlation between student perceptions and student grades (Pai et al., 2010).

Some studies used qualitative coding methods as part of the data collection. Kamin, O'Sullivan, Younger, and Deterding (2001) coded and recorded the occurrence of critical thinking characteristics that students displayed during a conversation. The instances of critical thinking supplied the quantitative data. The coding categorized the kind and degree of critical thinking displayed (Kamin, et al., 2001). However, Kamin et al., discovered that inconsistent coding was a flaw in their experimental design.

A mixed-methods approach using an experimental design with open-ended questions is consistent with the philosophy of CBT. A significant limitation, however, would be the increased scoring time and potential subjectivity in grading (Lundeberg & Yadav, 2006). A blind experimental design may eliminate grading bias, but consistency is an issue, even with a detailed rubric.

There is subjectivity inherent in creating scales and rubrics when blending quantitative and qualitative designs (Hays and Singh, 2012). Two examples of designs featuring subjective questions and rubrics are noteworthy. Grunwald and Hartman (2010) designed an experiment using open-ended questions as a summative assessment and compared a CBT group with a non-CBT group. The instructor was the same for both groups. The researchers used a rubric to help standardize the grading and codes to conceal the students. Two different individuals evaluated the test scores to independently verify the results. A second example is Noblitt, Vance, and DePoy-Smith's (2010) study, that compared two classes and graded the subjective questions with a rubric. However, the evaluators knew both the students and the groups.

There are at least two potential difficulties with these types of designs. One is that the instructor is the same for both groups. The instructor knows which class is using CBT and which class is not. There is the potential for the instructor to show greater enthusiasm, precise language, or different techniques to bias the results (Kuselman & Johnson, 2004). The other is the instructor created rubric. The subjective nature of the rubric will influence the outcome.

In summary, mixed method designs generally work well for evaluating the effectiveness of an educational methodology. With a mixed method design, the researcher analyzes the empirical data from test scores but also considers the perceptions of the participants. Nevertheless, researchers should show great care to eliminate confounding variables and construct appropriate tests to ensure legitimate results.

Further research is needed to investigate the possible correlation between case studies and the development of critical thinking skills. I used a quasi-experimental design to compare a test group with a control group. I administered a critical thinking assessment instrument to both groups multiple times to reveal a more comprehensive picture of the effect of CBT. By reducing the effect of confounding variables, the empirical results may reveal more clearly whether the directed case study method is a potentially useful teaching strategy that can help high school students develop critical thinking skills.

Synthesis of Research Findings

Case-based teaching methods are a subcategory of Problem-Based Learning (PBL). PBL is an instructional method characterized by introducing new content with a problem designed to engage students, and stimulate critical thinking (Woody, Albrecht, Hines, & Hodgson, 1999). The steps of the PBL protocol are identifying the problem, creating an action plan, researching relevant information, discussing the pertinence of the information to the

problem with a group, theorizing potential solutions, evaluating the solutions, reflecting on the process, and providing feedback to other group members (Yih Chyn & Huijser, 2011). Case-based teaching follows a similar process but differs slightly from PBL because the case-based teaching method uses the power of storytelling to relay the problem to students.

There are a variety of case study types; each type emphasizes different strategies and learning styles that can be suited to specific educational goals. If the instructional goal is developing student problem-solving skills and critical thinking skills, the literature indicates the PBL approach is beneficial (Dochy, et al., 2003; Schmidt, Van Der Molen, Winkel & Wijnen, 2009; Gijbels, Dochy, Bossche, & Segers, 2005). Case-based teaching is a strategy that can help teachers facilitate better comprehension and critical thinking in students. More specifically, the directed case study method is a good starting point (Herreid, 2005). The design of the directed case study method is conducive to reinforcing conceptual understanding (NCCSTS.org, 2017).

Most of the literature focused on the use of the directed case study method in college science courses due to the nature of the content-rich curriculum (Brickman, 2006; Cliff & Wright, 2006; Dinan, 2002; Kulak, Newton, Sharma, 2017; Missett et al., 2010; Popil, 2011). It is also used in biology (Pai et al., 2010), chemistry (Dinan, 2002), ecology (Camil, 2006) and anatomy and physiology (Cliff & Wright, 1996) courses to promote comprehension and critical thinking (Cliff and Curtin, 2000; Woody, et al., 1999). The directed case study is highly adaptable to a variety of courses and content.

Case-based teaching methods and PBL are frequently compared to traditional pedagogical methods with similar student achievement results on assessments in knowledge acquisition, and recall, but the PBL students tend to demonstrate better comprehension and application skills (Albanese & Mitchell, 1993; Capon and Kuhn, 2004; Dochy, Segers, Van den

Bossche, & Gijbels, 2003). Deeper understanding of content and the ability to apply information to new and different problems are characteristics of critical thinking. One of the features of PBL and case-based teaching is the opportunity to teach students critical thinking skills in conjunction with content.

Critical thinking is an ambiguous term used to describe cognitive abilities. Facione & Facione (1994) defined it as deliberate reflective judgment based on inferences and interpretation. Dochy, et al. (2003) emphasized that critical thinking is using systematic steps to reason. Popil (2011) characterized critical thinkers as individuals who logically search for the best possible outcome. In short, it describes a deep cognitive process where theories are tested, and ideas analyzed for the most desirable solution to a question or problem.

Developing critical thinking skills in students is important to education because both colleges and employers are looking for individuals with critical thinking skills. Problem-solving and critical thinking skills are essential for success (The American Diploma Project, 2004). College and career readiness may be defined as the preparedness of a student with academic proficiency, discipline to complete required tasks, critical thinking skills, communication, and social skills (Conley, 2012; The American Diploma Project, 2004; Wiley, Wiley & Camara, 2010). This changing economy requires students to be able to apply information to a variety of problems.

Teachers who want to prepare students for the job market face the difficulty of finding teaching strategies that work. The significance of a case-based teaching approach to science is to help facilitate the development of critical thinking skills in high school students. Case studies may improve student learning by requiring higher order thinking skills to solve real world problems. The improved learning and critical thinking is manifested in several ways. First,

Wolter, Lundeburg and Bergland (2013) concluded that case studies help students demonstrate deeper conceptual understanding and improved exam scores. Second, Montpetit, and Kajiura (2012) noted that students needed to use critical thinking skills to explain and interpret their case studies. The case studies Montpetit, and Kajiura used incorporated complex science problems, requiring students to analyze scientific research articles, and present the findings in class. They concluded that case studies require skills to investigate, formulate solutions, collaborate, synthesize, and summarize findings. Camil (2006) also found evidence of higher order thinking skills when he implemented case studies into his classroom teaching. Camil discovered that students could learn about the content, processes, and application of science concepts, in a single assignment.

Case studies can be adaptable to any level of Bloom's taxonomy, but are especially appropriate for higher level thinking, in applying scientific concepts to real world situations. Bloom's taxonomy is a scaffolding pyramid of learning goals with lower cognitive functions at the base and higher functions at the apex. Kunselman and Johnson (2004) noted that the active learning of CBT facilitates problem-solving and critical reasoning skills in students. Critical reasoning is a skill that transcends topics. Grunwald and Hartman (2010) identified the transferability of critical thinking to other topics as one of the features of teaching with case studies. If critical thinking is a prerequisite for college and career success, are high school teachers utilizing pedagogical methods to teach these skills to high school students? Kek and Huijser (2011) advocated for the deliberate instruction of critical thinking skills through PBL style formats, like case studies.

To review, case studies can be used by teachers as an active learning strategy. Case studies are a subcategory of PBL strategies. There are different types of case studies, but the

directed case study is advantageous for teaching objective content heavy classes. Directed case studies may be a useful tool for developing critical thinking skills in high school students.

Critical thinking skills are emerging as the defining characteristic of an educated person (Hunter, 2015).

Critique of Previous Research

There are several inconsistencies within the current research of CBT that weaken the claims of CBT. The weaknesses include: varying degrees of implementation, using different types of cases in a single course, and differing expectations instructors have for CBT. Taken together, these insufficiencies obfuscate understanding the efficacy of CBT. Each of these criticisms are discussed in the following paragraphs.

The ambiguous nature of implementing CBT into a classroom is one of the advantages as well as one of the detriments of CBT. The advantage is that the methodology can be customized to fit an educator's learning objectives, but the lack of standardization makes identifying the reasons for the results difficult to ascertain. For any teaching method there are degrees of implementation (Albanese & Mitchell, 1993; Dochy, et al., 2003; Kek & Huijser, 2011). At the one end of the spectrum a nursing program designs the entire curriculum experience around CBT. While on the other end the solitary science teacher in the department uses one clicker-case to spice up a single lecture (Glew, 2003; Montpetit & Kajiura, 2012). In between, are individuals and organizations that use case studies to varying degrees. One institution even used a case study across disciplines to integrate Biology, American History, and Psychology classes (Nava-Whitehead, Augusto, & Gow, 2011). The flexibility of CBT allows for customization by teachers, departments, and institutions to shape the application of case-based methodology to fit the educational objectives. However, that ambiguity also creates confusion. At what degree of

implementation is CBT most effective? There is no adequate answer to this question in the existing literature.

Adding to the confusion is another ill-defined variable; the types of case studies used. The National Center for Teaching Case Studies in Science website (2017) listed fourteen distinct types of case study designs. Each different type of case study is designed to cater toward achieving an educational goal. National Center for Teaching Case Studies in Science administrators encourage instructors to choose the case study based on the intended course outcomes, the desired level of student interaction, the amount of modification necessary to customize the lesson plans, and if the story will be revealed progressively to the students. The wide variety of case studies available offer educators the advantage of finding a design that suits an educational objective. But the wide variety of case study designs adds confusion to the research by raising compelling questions. Is one case study design superior to the others? Does each specific design lead to predictable benefits? Is CBT most effective when a combination of designs is used and what is the best combination? The literature seems to support the general benefits of CBT, but do the specific designs affect the results or is choosing a design simply a matter of personal preference? Although Herreid (2004) alleged that the interrupted case study is the most effective for teaching critical thinking skills, the literature does not seem to sufficiently address this question.

A third, and final, weakness in the literature is the varying expectations instructors have of CBT. At issue here is the question: "What are the benefits of CBT?" For some the primary benefits are content knowledge and test scores (Cliff & Wright, 1996; Sendag & Odabasi, 2009). Others focus on problem-solving skills or group interaction skills. Still others tout critical thinking or the development of research skills (Kunselman & Johnson, 2004; Noblitt, Vance, &

Smith, 2010). Most authors seem to primarily support one benefit but insist that other secondary benefits are garnered along the way. The reason these varying expectations create confusion in the literature is that experimental testing methods are influenced by the expected results. For example, in one study the CBT classes and the lecture classes scored basically the same on a content test (Pindiprolu, Peterson, Rule, & Lignugaris-Kraft, 2003; Sendag & Odabasi, 2009). Should the researcher dismiss CBT based on poor academic results? Or should the researcher praise CBT for both proficiency in content and growth in group interaction skills? The connection between CBT and what exactly to expect as a result is not sufficiently dealt with in the literature.

The research on CBT is growing, but many gaps remain. To better close those research gaps, some of the key assumptions and characteristics of CBT should be clarified. At least three insufficiencies should be addressed to bolster the CBT research: the degree of implementation, the benefits of each specific case study design, and the expected results of using CBT. This dissertation intends to redress some of these issues by designing an experiment that defines the degree of implementation, utilizes a specific case study method, and tests for the correlation between the case study method and a specified outcome.

Summary

CBT is an active learning method that teaches students to analyze real world stories (Fossy & Crow, 2011). CBT is one example of problem-based learning strategies. PBL strategies are characterized by cooperative teams of students researching and critically analyzing authentic, relevant problems in a systematic way (Klegeris & Hurren, 2011). Of all the case study methods, the directed case study method is best suited for content rich classes (Brickman, 2006). The distinguishing feature of the directed case study is the objective nature of the

questions asked throughout the narrative. This feature of objective questions lends itself to empirical studies. Empirical studies can assist educators in discerning which new ideas are effective teaching methodologies (Slavin, 2003). Effective teaching methods ought to improve more than just test scores, effective teaching methods should also develop critical thinking skills (Grunwald & Hartman, 2010).

Constructivist theory aligns well with active learning strategies, because the constructivist framework asserts that the responsibility is on the students to use critical thinking skills in the acquisition of knowledge (Qarareh, 2016). According to constructivist theory, students acquire new knowledge by comparing any new information with previously constructed paradigms. The student researches various databases to reconcile the inconsistencies between the two, remodeling their conceptual framework. Essentially, the steps to using a directed case study are modelled along the lines of constructivist theory (Hunter, 2015). First, the students are confronted with a difficult problem written in story form. Next, the students pool their knowledge and research to analyze the problem and potential solutions. Finally, the students formulate an argument that justifies the most viable solution. This constructivist approach to problem-solving not only provides a relevant context for learning, but also lends itself to the development of critical thinking skills.

A review of the current literature found that the case study method could be adapted from business and law to science and medicine (Herreid, 2005). Research indicated that instructors looking for active teaching methods found that case studies help to build student knowledge, provide a relevant context for learning, and foster critical thinking (Camill, 2006). However, little empirical evidence exists that supports the claim supporters make about case studies developing critical thinking. Additionally, a wide range of implementation issues belie some of

the benefits of CBT touted by supporters (Dochy, Segers, Van der Bossche, & Gijbels, 2003; McFarlane, 2015). Despite the rich heritage of CBT, little quantitative research has been done to verify the claims.

Typically, researchers employ surveys for descriptive or correlational studies to answer questions about CBT. Fewer studies are quasi-experimental, and none are controlled experiments. There are significant obstacles to conducting a controlled experiment to investigate the effectiveness of a teaching strategy. Arguably, quasi-experimental designs provide the most informative data regarding the efficacy of CBT in the arenas of content knowledge, application, and problem-solving. More quantitative research is needed to back the claim that CBT enhances the development of critical thinking skills.

Critical thinking skills are becoming a defining characteristic of educated individuals in the 21st century (Beers, 2005). Nevertheless, educators struggle with finding teaching methods that consistently assist in developing the critical thinking of students (Herreid, 2001). Active learning methods, like using case studies show some promise in this area (Prince & Felder, 2006). However, there are different types of case studies, each offering some advantages. The directed case study method is especially conducive to content rich classes, and may be a useful tool for developing critical thinking skills in high school students.

The previous research on CBT has primarily focused on student content knowledge and attitudes toward learning with case studies. Many questions about CBT remain unanswered. The first step toward systematically answering research questions would be to clearly describe the specific type of case study design used for the study. The second step would be to standardize the degree to which the case study design would be implemented by the instructor (McFarlane, 2015). The final step would be clearly hypothesizing the intended results of using case studies.

This dissertation intends to model a research design that focuses on some of these issues. This study explored any potential correlation between the directed case study method and the development of critical thinking skills using a quasi-experimental research design.

Chapter 3: Methodology

The purpose of this study was to quantitatively investigate the effect of case-based teaching on the development of high school students' critical thinking skills. Case-based teaching (CBT) methods utilize constructivist learning theory in a systematic approach to help students solve case study problems. The literature indicates a CBT learning framework that emphasizes systematic problem solving will facilitate the growth of critical thinking skills (Centin-Dinar, 2015; Noblitt, Vance, and Depoy-Smith, 2010). In this chapter, the research design, research context, sampling, research instrument, research analysis, study limitations, expected findings, and ethical issues are discussed in detailed.

This study is significant for several reasons. The first is the premium placed on critical thinking skills by employers and colleges (Conley, 2012). Instructional methods that foster critical thinking are often the first choice of educators seeking to prepare students for the future. The second is the effect of case studies on student performance. Case-based teaching has been shown to deepen understanding, spark student motivation, and improve test scores (Grunwald & Hartman, 2010; Kunselman & Johnson, 2004; Wolter, Lundeberg, & Berland, 2013; Wright & Wright, 2005). Third, this study could encourage a practical approach to education; from knowledge to wisdom. If wisdom is knowledge put into practice and applied, then case-based teaching may help students find practical applications to their factual knowledge. As students practice applying their knowledge through CBT, they can develop the habit of applying their knowledge to other areas of life

Fourth, this study could encourage teachers to take an active-learning approach to education. Teachers could receive training on incorporating CBT, the benefits of active learning strategies, and the importance of choosing strategies that best meet the philosophical and

educational goals, and which research methods are reliable. This professional development could inform teachers' decisions as they prepare their daily lesson. One of the potential results is that teachers may also customize and compose case studies that fit their curriculum. Composing customized case studies benefits both students and colleagues. Teachers who are creative can write compelling case studies that may be useful as lessons or inspire others to write original case studies. Fifth, there exists a lack of quantitative data in the literature describing the effect of CBT on students' critical thinking skills. Some authors in the literature review referenced qualitative observations linking critical thinking development and case studies, but there is a lack of quantitative data to support the assertion. This study was needed to provide quasi-experimental evidence that may begin to narrow that research gap.

This study utilized a quasi-experimental design. A quasi-experimental design is both a practical approach to evaluating the effectiveness of teaching methods and can yield reliable quantitative data for research studies (Creswell, 2014). A quasi-experimental study is different from an experimental design because the grouping is non-random; the groups of students are already assigned to a classroom. The research design followed a repeated measures format. The study consisted of an initial test administered to both a control group and experimental group. The instructors in the control group presented science material to students using traditional teaching methods, i.e. lecture. The instructors in the experimental group presented the science content using two directed case studies. A second benchmark assessment was administered at the midpoint. The experiment concluded with a test given to both groups approximately six weeks later. The test score data was analyzed to determine if the use of directed case studies caused growth in students' critical thinking skills.

Purpose of the Study

The purpose of this quasi-experimental study was to investigate the use of a directed case study teaching method on the critical thinking skills of high school students. No single teaching method can achieve all educational goals however, knowing the strengths of a methodology can help educators align methods with purposes. As more information about novel methods become available, teachers can make informed decisions about which method to use.

Research Question

The research question that guided this study was: Will students taught using the directed case study method have higher mean scores on a series of critical thinking assessments compared to students taught using the teacher-centered method?

H₀₁: The mean test scores on the critical thinking assessment one, two, and three will be equal regardless of group (There is no main effect for the time factor over three levels).

H_{A1}: The mean test scores on the critical thinking assessment one, two, and three will not be equal regardless of group (There is a main effect for the time factor over three levels).

H_{O2}: The mean test scores on the critical thinking assessment of the students instructed using directed case studies will be equal to the mean test scores of students instructed using teacher-centered methods (There is no main effect for the group factor over two levels).

H_{A2}: The mean test scores on the critical thinking assessment of the students instructed using directed case studies will not be equal to the mean test scores of students

instructed using teacher-centered methods (There is a main effect for the group factor over two levels).

HO₃: There is no difference in the mean scores on the critical thinking assessment for any factor level combination. (There is no interaction effect).

HA₃: There is a difference in the mean scores on the critical thinking assessment for any factor level combination. (There is an interaction effect).

Research Design

This quasi-experimental approach used a repeated measure design to assess the critical thinking skills of high school students. Using a repeated measures design strengthens the study by adding more data points while reducing error when compared to a pre-post-test design. One of the threats to a pretest/posttest design is the influence of external factors over time.

Additional data points clarify the effect is due to the treatment, establishing a pattern of growth. Benefits of a repeated measures design include increasing statistical power, requiring a smaller number of participants, and detecting the effect of case studies over time (Frost, 2018). Although repeated measures designs may require more analysis, the data acquired can reveal a more comprehensive picture of the effect of CBT.

The assessment of non-equivalent groups determines the potential difference in growth between the directed case studies group and a non-case study groups' critical thinking scores. First, the study requires a control group and an experimental group consisting of 9th and 10th grade public school biology students. The experiment followed a repeated measures design, as illustrated in Figure 1.

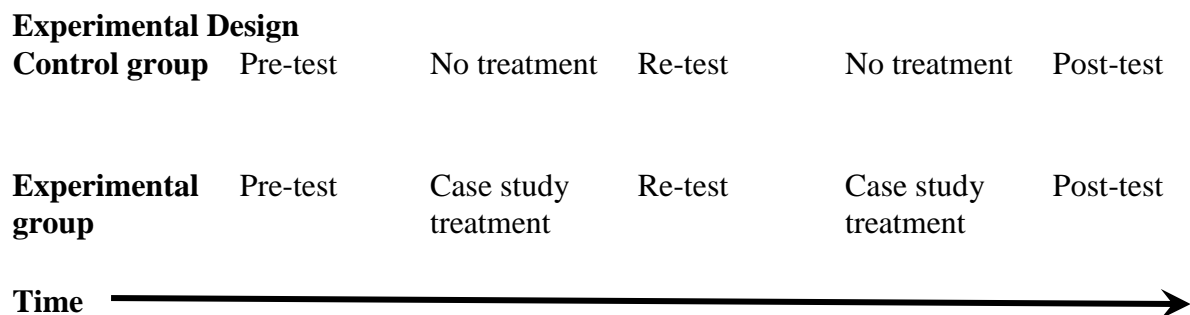


Figure 1. Quasi-experimental repeated measures design adapted from Creswell (2014, p. 310).

Both groups began the study by establishing a baseline score. After establishing a baseline, the control group instructor(s) taught the classes using traditional methodologies including lecture, guided practice, or cooperative learning strategies. The experimental group instructor(s) used two directed case studies over the course of approximately six weeks. These instructors were encouraged to select directed case studies from the archives of the National Center for Teaching Case Studies in Science and follow the accompanying lesson plans. Both groups retested at the three-week interval. The control and experimental groups experienced a second three-week iteration of the same treatment, unlike a related groups design. All students took a third version of the critical thinking assessment as a posttest.

The instructors in the experimental group were encouraged to use directed case studies selected from National Center for Teaching Case Studies in Science. The instructors selected directed case studies based on convenience, topic, or familiarity. Some instructors chose case studies from other sources. The content of the case studies should not matter for two reasons. One reason was that the assessment is related to critical thinking, not specific science content. The second reason was the focus of the study on the delivery method rather than the material

delivered. The instructors were instructed to implement the directed case studies using the teaching notes provided by the National Center for Teaching Case Studies in Science.

Testing Procedures

Testing protocols for this study were adopted from Insight Assessment (2016). The proctors ensured the computers worked properly, maintained a distraction free environment, refused to comment on or clarify the questions, and collected materials at the end of the session. Students logged into Google Classroom to access the test or opted to take the paper and pencil version. Students completed the 25-minute test individually and unassisted.

Participants

The study was conducted at a large semi-urban high school in the United States. Generally, large high schools have a diverse student body and heterogeneous classes. The high school had a student population of around 2,000; consisting of slightly more males than females (National Center for Education Statistics, 2016). The ethnicities represented included Caucasians, Hispanics, Blacks, American Indians, Asians, and some who were two or more races (National Center for Education Statistics.gov, 2016). According to the National Center for Education Statistics (2016), the school employed over 120 teachers in grades nine through 12. Within the total population of 2,000 students, slightly over half (51%) were part of a free or reduced lunch program (National Center for Education Statistics.gov, 2016). Based on this data, nearly 50% of the students who attend the school need some government assistance. The school district spent an average of US \$15,000 dollars on each student, almost \$2,000 more than the state average (Public School Review, 2014). The graduate rate was close to the state average of 84%; however, 68% of Blacks and Hispanics graduated, while 89% of Caucasians, and 91% of Asians graduated (Great Schools, 2014). The state standardized testing data showed

approximately 20% earning proficient or better in Algebra I, 55 % earning proficient or better in Biology, and 55% earning proficient or better in English (Great Schools, 2014).

The sample for this study was 9th and 10th grade science students in general-level classes at one school. An *a priori* power analysis for two-factor repeated measures analysis of variance indicated that with a moderate effect size (.25) five percent error probability (.05) and 95% explanatory capability (power = .95) a sample of 142 students was required. However, in the interest of increasing the power of the study, diminishing the influence of extraneous variables, and anticipating a small effect size, the desired sample size was 300 participants ($n = 300$). The control group consisted of classes selected randomly from teachers willing to participate, the remainder were in the experimental group. Teachers were provided with some CBT basics; overview presentation, articles, and lesson materials.

Instrumentation and Data Collection

The original open access test by AssessmentDay was used as a question pool to create three smaller testing instruments. The question pool consisted of four sections corresponding to four characteristics of critical thinking: assumptions, deductions, interpreting information, and analyzing arguments. Each section consisted of several prompts and each prompt had three to four “either/or” style assessment items related to it.

The question pool was used to create three 20-question assessments that can be used as multiple measures. The smaller tests were converted to an electronic format and consisted of questions from the four categories. The entire prompt with its three to four corresponding questions was used. The three assessment instruments had 20 items: three to four testing assumptions, six testing deductions, three testing interpretations, and seven to eight testing arguments. The time limit for each testing session was 25 minutes.

The tests administration was made available using Google Classroom or using a paper and pencil version. The Google Classroom platform collected item level data from each student, the paper and pencil data must be collected manually. Student names and individual scores were not relevant to the study, but the question level data was analyzed for reliability testing, and test scores data were analyzed for growth. The total scores for each group's performance on the test were compared statistically.

Pending complications with access to the online Google Classroom, an alternative paper test version was offered. Classroom instructors were given a script to read that outlined the testing protocols. Teachers were also provided with a set of randomized identification numbers that were assigned to the student participants. The students wrote the random identification number on both their test and the answer sheet. After the testing sessions, the instructor collected the tests and answer sheets, and placed them into a sealed envelope. The envelope was collected and stored in a locked location.

A two-factor repeated measure analysis of variance was used in testing the hypothesis and answering the research questions guiding the study (Ellis, 1999). There are two underlying assumptions of two-factor repeated measures analysis of variance. The first assumption is normality of the data, which can be tested numerically using SPSS. The second assumption is sphericity; where the "variance of the difference between all combinations of related groups are equal" (Laerd Statistics, 2015). Mauchly's Test of Sphericity was used to test this assumption. A violation of sphericity leads to an increase in the chance of a type 1 error. If a violation does occur, corrections can be applied to the degrees of freedom to obtain a valid F -value (Laerd Statistics, 2015). Post-hoc analysis of the two-factor repeated measures analysis of variance were used to identify which means were different and evidence of growth.

Examination of the Psychometric Properties of the Instrument

The AssessmentDay practice test is not advertised as a validated test but has been used by some researchers. Any instrument used in an experiment should have some threshold of reliability and validity and be put to proper use (Camines & Zeller, 1979). However, validity is an inference to the degree of test accuracy and cannot be measured perfectly (Cook & Beckman, 2006). This testing instrument rests on the face validity claims made by AssessmentDay, Ltd. An open access validated critical thinking assessment may be a useful resource for future studies. This study did incorporate some reliability testing of this instrument.

AssessmentDay is a testing company that supplies practice tests in categories such as aptitude, personality, and critical thinking. The practice tests are designed to help potential customers succeed on common aptitude tests used by potential employers. The tests are advertised as constructed by experts in the field (AssessmentDay, 2015). Aside from face validity, there is no record of other validity testing for the practice assessment. Part of the reason is that the assessment items consist of both Likert scale and binary options. Taken in its entirety, this format precludes factor analysis. The instruments used in the study consisted of the binary items, limiting the validity testing. Nevertheless, Khonamri and Farzanegan (2016) used the raw scores of this instrument in a pre and posttest quasi-experiment. A Kolmogorov-Smirnov analysis of pretest scores yielded a normal distribution and Levene's test showed homogeneity between the groups (Khonamri & Farzanegan, 2016). These findings indicate that the instrument can be useful for investigating the assumptions of the general linear model.

This study conducted some reliability testing on the binary items used in the assessments. Kuder-Richardson Formula 20 was used to analyze internal consistency reliability. The Kuder-

Richardson Formula 20 is used to compute the reliability of binary or dichotomous responses. A result of .6 or higher indicates the questions are consistently measuring the intended construct.

Operationalization of Variables

The pertinent data for this study was the mean of the overall scores on the assessments, rather than the categorical scores, because of the holistic nature of critical thinking. The overall score reporting was based on the number of questions answered correctly. For this study, growth was defined as a statistically significant positive change in the mean of the overall scores. The defining characteristics of a directed case study are objective questions and short scenarios. The purpose of this introductory case method is to review fundamental facts and concepts (National Center for Teaching Case Studies in Science). The National Center for Teaching Case Studies in Science provides a list of acceptable possibilities by searching the database with the term “directed” (National Center for Teaching Case Studies in Science). For this study, the chosen method to represent CBT was the directed case study.

Preparation of Data Before Analysis

The use of two-factor repeated measures ANOVA within the general linear model carries two design assumptions and three analysis assumptions. The design assumptions include a dependent variable measured at the interval level (for example, test scores) and at least two categorical independent variables (for example, groups) (Laerd Statistics, 2015). The analysis assumptions include the absence of significant outliers, equal variance between groups, and sphericity. These three analysis assumptions were tested to determine the proper course of data analysis.

The first step was to examine the data for outliers (Carey, 2018). Outliers may be the result of students not taking the testing seriously or clerical error. If outliers are present

mitigation measures include running a sensitivity analysis. A sensitivity analysis provides researchers insight into the extent the outliers influence the data, and if non-parametric testing is warranted (Zaiontz, 2018). Parametric tests were used with the data, because no outliers were found. The second step was to test the assumption of homogeneity of variance using Levene's test (Carey, 2018). Homogeneity of variance is the assumption that the variance within the groups is equal. If the p value is lower than .05 the data violates this assumption, and an alternative to the two-factor repeated measures ANOVA would have been used.

The third step was testing for the assumption of the normal distribution of the data. Although a visual inspection is an option, it is not generally recommended. Typically, Kolmogorov-Smirnov and Shapiro-Wilk tests are the most commonly used (Ghasemi & Zahediasl, 2012). These tests compare the sample data to a bell curve. For this study the Shapiro-Wilk test was the preferred method because it has more statistical power than the Kolmogorov-Smirnov test (Thode, 2002). A violation of the normality assumption would have required non-parametric statistical analysis. Non-parametric statistics provide an alternative analysis when the generalized linear models assumptions are violated.

Data Analysis Procedures

This research design compared the growth of the experimental group with a control group. The groups were heterogeneous and nonrandom, but the potential for a large sample size ($n = 300$) would have increased the accuracy of the sample's representation of the actual population. The mean differences across multiple measures of the two groups were analyzed using a two-factor Repeated Measures ANOVA. The decision rule for significance of growth was an alpha of .05.

This .05 decision rule can be maintained despite multiple tests by using an alpha controlling procedure such as Bonferroni, false discovery rate, or Ryan-Einot-Gabriel-Welsch (Cribbie, 2003). By comparison, using a series of *t*-tests increases the chance of finding a false significant result. Shaffer (1995) observed that the chance of a Type 1 error increases with the number of hypotheses tested. A post-hoc, multiple comparison test was necessary to determine where any potential differences in growth might be found.

A two-factor Repeated Measures ANOVA was especially fitting for analyzing the three test scores in this study design (Laerd Statistics, 2015). The two-factor Repeated Measures ANOVA is useful because it measures statistical differences between groups when there are multiple levels of the dependent variable and the groups are related (Adams & Lawrence, 2015). The logic of using an ANOVA was to determine if teaching with directed case studies is related to greater change in critical thinking than chance alone. Ellis (1999) contended that the research hypothesis ought to be tested by the most rigorous design and subsequent statistical analysis. In this case, a repeated measures design was more rigorous than using *t*-tests to compare pre/post test scores. The additional data points provided a more comprehensive picture of changes while controlling for Type 1 errors. Moreover, repeated measures designs are conducive to testing inferences of change over time (Ellis, 1999).

This study's two-factor repeated measures ANOVA analysis used an alpha of .05. The mean results were used with the multivariate *F* test to determine if there was any statistical significance. Next, the results of the test for with-in subjects effects, with-in subjects contrasts, and between subjects effects were inspected. If a significant difference was detected, the partial eta squared statistic was interpreted to ascertain the effect size of directed case studies on critical thinking (Kupczynski, Mundy, & Ruiz, 2013).

Limitations and Delimitations of the Research Design

Quasi-experimental designs cannot account for all confounding variables. There were four considerations specific to this study. First, this research study was not conducive to random sampling, because the students were already grouped into predetermined classes. Second, the instructors were aware of the repeated measures, and the comparison between the independent and dependent variables. This information may have led to resentful demoralization because the control group perceives a less desirable treatment or compensatory rivalry because the control group worked harder to compete with the experimental group (Creswell, 2014). Third, the specific content of the lessons may have proven problematic, since the experimental protocol permitted teacher choice. However, the AssessmentDay test was not subject specific; therefore, the lesson topics should have been irrelevant. A final consideration was the degree of implementation. Teachers could have brought their own ideas, points of emphasis, level of enthusiasm, modifications, and interpretations to any lesson. The teaching notes may have facilitated some degree of standardization, but conformity was an impossibility.

Internal and External Validity

Quasi-experimental designs have more internal validity threats than true experiments (Creswell, 2014). Creswell (2014) listed at least five potential threats applicable to this study: history, maturation, selection, testing, and mortality. Each of these threats and potential solutions will be discussed in the following paragraphs.

The first threats to consider are history and maturation. The passing of time may introduce extraneous factors that influence the test results, including information in other classes, and activities outside of school. There may be maturity difference between 9th and 10th grade students as well as the potential that individuals may mature during the six-week time frame.

Solutions include sampling populations restricted to 9th and 10th graders instead of the entire high school, focusing the study on the critical thinking growth rather than content, and using repeated measures rather than a pre/posttest. This decision reduces the ability to make wider generalizations based on the results.

The next threats to consider were selection and mortality. Selection to this study meant choosing teachers who are already skilled at CBT for the experimental group. Selection was not particularly confounding because none of the teachers were proficient with CBT. Enthusiasm with CBT or modification to lesson plans may have introduce extraneous factors. However, the control group instructor may have also been conversant or enthusiastic about their pedagogy. Mortality posed a significant threat because a single teacher dropping out could have dramatically reduced the sample size. The problem of mortality may have been alleviated by a larger sample size.

Finally, there were two threats from the testing procedures. One was the test familiarity that results from using the same test multiple times. Test familiarity was not a significant factor, since the assessment from AssessmentDay was used as a pool for constructing three smaller assessments. The second testing problem was the potential for students not to take the testing seriously. The counter-measure included eliminating sample scores that show less than 60% completion or that were finished in under a third of the allotted time limit. Additionally, allowing students to see their scores may have helped motivate the students to do well.

Expected Findings

I expected the use of directed case studies to improve critical thinking scores. The literature review indicated a positive relationship between active learning strategies and critical thinking (Camill, 2006; Chaplin, 2009; Grunwald & Hartman, 2010; Kunselman & Johnson,

2004; Montpetit & Kajiura, 2012; Noblitt, Vance, & Smith, 2010). If directed case studies are effective at building critical thinking skills in high school students, the positive effect should hold true. However, CBT is relatively new, and few studies attempt to quantitatively measure the effect on critical thinking. This study could help teachers evaluate the effectiveness of CBT. The art of teaching is partly finding the best methodology to attain the desired results. Research can help align methods to outcomes, even by eliminating possibilities. Therefore, if no direct effect was found, the study could still inform the literature by narrowing the scope of CBT effectiveness.

Ethical Issues

Quasi-experimental methodological studies are subject to several ethical considerations. Cohen, Manion, and Morrison (2011) urged weighing the benefits of the research against the risks and taking the necessary precautions. Quasi-experiments carry over many of the ethical concerns and the strengths afforded by true experiments, many of which can be divided into three categories: issues with the design, teachers, and students. Each category will be addressed in the following paragraphs in order.

Design Issues

Design issues were the first area of concern. First, collecting student test scores created security risks. The individual's identity and test results were protected by using multiple layers of security protocols, but the process exposed students to the risk. Second, teachers had little experience with CBT. Third, the relationship between student and teacher may have influenced the students' perception and performance. Finally, the possibility existed of students encountering ineffective teaching techniques and experiencing educational gaps.

Teacher Issues

Another area of concern was teacher-related issues. One was that, for the duration of the study, the author was a faculty member at the institution responsible for the sample population. Even though the sample participants come from other classes, students may have felt threatened or uncomfortable participating in a research study by a teacher. A second area of concern was other teachers in the same department as the independent and dependent variables. Teachers may have perceived the treatment as beneficial and complained about being in the control group or vice-a-versa. Student performance may have been influenced by teachers positively encouraging students to do well or conversely, fostering negativity. Lastly, impinging on co-workers may have created issues with professional relationships.

Student Issues

The final category of potential concerns consisted of student-related issues. Students may have balked at the thought of additional testing, and the fear of poor performance. Students may have not completely understood the concept of voluntary informed consent. The wording of the permission slips could have created confusion causing some to participate who would rather not. The responsibility of returning a permission slip biased the study toward responsible and/or organized students. Students could have been likely to forget their right to withdraw, and that no coercion or duress was used to compel their participation.

Summary

This quasi-experimental experiment sought to investigate the effect of directed case studies on the development of critical thinking skills. The study followed a repeated measures design. According to constructivist learning theory, active learning strategies augment cognitive processing and problem-solving. Arguably, CBT facilitates the development of critical thinking

through student engagement in the investigative process. The expected outcome of the study was that there would be greater critical thinking growth in the experimental group.

A second aspect to the study was developing and using the testing instruments. The testing instrument items were pooled from the AssessmentDay critical thinking test. The modified versions were tested for reliability, while the face validity rests on the test construction by professional writers. The total test scores of the repeated measures for the control group and experimental group were statistically compared using a two-factor Repeated Measures ANOVA. The target population was 9th and 10th grade general biology students in a large semi-urban high school.

There were some potential threats, limitations, and benefits inherent in this study. Threats to the validity of the experimental results included the effective use of CBT, mortality, and a lack of student interest. Additionally, the ability to generalize the study to other populations is limited. Nevertheless, one benefit of the study was providing a potentially useful testing instrument to evaluate critical thinking using other teaching methods. A second benefit of the study was assisting teachers in making methodological decisions to achieve their educational goals. Teachers that incorporate strategies demanding critical thinking skills are equipping students to compete in the evolving job market.

Chapter 4: Data Analysis and Results

This quasi-experimental study examined the potential relationship between the directed case study teaching method and the critical thinking skills of high school students. The directed case study method incorporates the use of a story to communicate content (Herreid, 2005). Whereas, critical thinking skills describe a student's systematic approach to problem-solving through the application of known facts to new information (Kuhn, 1999; Willingham, 2007). The participants were 9th and 10th grade students enrolled in a general biology class at a large, rural, public high school. A non-case study group and a case study group were given the first critical thinking test to establish a baseline. Then the case study group experienced the directed case study method, while the non-case study group received didactic instruction. Didactic instruction describes teacher-centered instructional methods, such as lecture. The subsequent critical thinking instruments were administered at the midpoint and end of the study.

This chapter presents the demographics data, instrumentation data, and the statistical analyses used to interpret the data. The demographics were based on non-random sampling because the classes were already intact, and participation in the study was voluntary. The instrument was an open access test authored by AssessmentDay. The data was analyzed using a two-way mixed repeated measured ANOVA with the associated assumptions and post-hoc tests. This chapter presents the findings of the study.

Description of the Sample

Seven of the nine biology teachers in the high school volunteered to participate in the study. Among the volunteers were four females and three males, three of the teachers had less than 10 years of experience, one had between 10 and 20 years of experience, two had between 20

and 30 years of experience, and one had over 30 years of experience. The teacher demographic data is displayed in Table 1.

Table 1

Participating Teachers' Gender and Experience

Teacher	Gender	Years of experience
1	Female	< 10
2	Female	< 10
3	Male	< 10
4	Female	20–30
5	Male	10–20
6	Male	> 30
7	Female	20–30

The participating teachers introduced the study to their students by reading a script explaining the purpose of the study, who was conducting the research, and the expectations (see Appendix F). The participating teachers distributed parental consent forms to the students in their classes (see Appendix D). Students were instructed of the need for both written parental consent and student assent. The following day, the researcher visited all the classes and provided an overview of the study, answered questions, and offered the enrollment incentive of winning one of four iTunes gift cards. The sample was restricted to the on-level general biology students, as opposed to the honors biology track. Biology is a course that spans two entire school years. The students in 9th grade are enrolled in Biology I, while 10th graders are enrolled in Biology II. Students who fail are required to retake Biology II, so there are three 11th grade students in the sample.

As anticipated, garnering participation from general level biology students was difficult. Heath, Charles, Crow, and Wiles (2007) contended that student participation in research studies is often stymied by layers of obstacles including institutional gatekeepers, parents or guardians, and ongoing consent from student participants, despite age appropriate personal agency. Even if there is initial receptivity, participants may lose the permission slips, forget to return them by the deadlines or feel too inconvenienced by the process (Unger et al., 2004). Generally, these difficulties contribute to the low participation rates as described in the preceding paragraph.

All 529 general biology students received parent consent forms and were given the incentive of an iTunes gift card drawing for returning the parent consent form. Both the participating teachers and the researcher explained the content of the forms. The parental consent forms were also available in Spanish. Students who returned the parental consent forms were given student assent forms to sign. These assent forms were written in grade-level language (see Appendix A). Requiring both parental consent and student assent is consistent with ethical adolescent research practices (Unger et al., 2004). Initially, 92 students completed the enrollment process by submitting the signed forms, making the response rate 17%. Student participants remained in classes with non-participants. There was an unequal number of student participants recruited from each teacher as portrayed in Table 2.

Table 2

Number of Student Participants Recruited by Participating Teachers from Their Classes.

Teacher	Number of students recruited
1	19
2	4
3	10
4	15
5	27
6	1
7	16

The initial sample totaled 92, but 13 students dropped out either by choice or by defaulting on one of the repeated measures, making the attrition rate 13%.

The teachers were chosen randomly to be part of the non-case study or the case study groups before the student recruitment process was complete. There were not as many students recruited from the non-case study group classes as anticipated. Since the teachers in the case study group already made plans to incorporate CBT, the groups were left intact. The final sample population consisted of 62 in the case study group and 17 in the non-case study group ($n = 79$). More females (65%) opted to participate in the study than males (35%). Most participants identified themselves as Caucasian (62%); the next largest group identified as Hispanics (15%); followed by “other” which included bi-racial participants (15%); only four participants identified as African American and two as Asian. The age range stretched from 14-year-olds to 17-year-olds. The largest representation was 15-year-olds (49%), then 16-year-olds. (30%) followed by

14-year-olds (16%) and lastly, three 17-year-olds. The demographic data of the participants is displayed in Table 3.

Table 3

Demographic Data Including the Gender, Age, and Race of the Student Participants.

	Total sample	Non-case study group	Case study group
Gender			
Male	28	3	25
Female	51	14	37
Age			
14	13	0	13
15	39	11	29
16	24	6	17
17	3	0	3
Race			
Caucasian	49	10	39
Hispanic	12	3	9
Other	12	2	10
African-American	4	2	2
Asian	2	0	2
Total Participants	79	17	62

Instrumentation

The instrument used to measure critical thinking skills was an open access critical thinking test authored by AssessmentDay. AssessmentDay is company that offers practice

standardized tests to individuals intending to take tests such as the Watson-Glacier Critical Thinking Test (AssessmentDay, 2015). The open access critical thinking test consisted of 86 questions divided into five categories: 14 questions about inferences, 14 questions about assumptions, 21 questions address deductions, 12 questions focus on interpreting information, and 25 questions analyze arguments. AssessmentDay (2015) defined inferences as a conclusion that can be drawn from observable facts; assumptions are presuppositions or facts taken for granted; deductions are a means of extrapolating information from the statements given; interpreting information requires drawing an appropriate conclusion; and analyzing arguments requires distinguishing between an argument that is directly related to the information from an argument based on inconsequential information. The inference questions were Likert scale, while the remaining questions were dichotomous. Examples of questions from each category are provided in Table 4.

Table 4

Example Questions From Categories of Critical Thinking Assessments.

Category	Stem	Question
Assumptions	Monarch nations, i.e. those with royal families, differ from republican nations in several ways. An example of this difference is that citizens of monarch nations pay more tax than citizens of republican nations.	The governments of monarch nations are responsible for setting tax rates on their citizens. a. Assumption made b. Assumption not made
Deductions	Sarah owns a new company. New companies are more likely to fail than well established companies. Therefore:	Sarah's company will fail. a. Conclusion follows b. Conclusion does not follow
Interpreting information	The British National Library has the largest collection of publicly-owned books in the United Kingdom. Therefore:	There might be a larger collection of books in the United Kingdom. a. Conclusion follows b. Conclusion does not follow
Analyzing arguments	Should companies downsize their workforces to decrease expenses and maximize profits?	Yes, downsizing will protect the company from bankruptcy in hard economic times. a. Strong argument b. Weak argument

The open access assessment was used as a question pool to create three 20-question instruments for the repeated measures. Each 20-question assessment had approximately the same number of questions chosen from the categories: Assumptions, Deductions, Interpretation, and Analyzing Arguments. The items chosen from each category consisted of the short stem statements or paragraphs and all the accompanying questions available. For example, the items in the Assumptions category on Assessment 1 consisted of one stem and four associated questions. Therefore, the stem statements and questions were chosen so that the number of questions in each category would be approximately equal. The layout of each critical thinking instrument

included identical directions for the test, and expectations for each category of questions. The distribution of the questions is displayed in Table 5.

Table 5

Number of Questions in Each Category in the Critical Thinking Instruments Used in This Study.

	Assumptions	Deductions	Interpretations	Analyzing arguments
Assessment 1	4	6	3	7
Assessment 2	4	6	3	7
Assessment 3	3	6	3	8

Validity

Prior to constructing the instruments, consideration was given to its validity. There were three categories of validity used to evaluate the instrument: content, construct and criterion (Heale & Twycross, 2015). Isaksen and Ekvall (2015) stated that content validity is more a matter of expert opinion than statistical analysis. However, neither expert opinion nor statistical analysis was readily available. Nevertheless, the use of the test is not without precedent. Khonamri, and Farsanegan (2016) utilized the assessment in its entirety to analyze critical thinking skills of university students. The twenty items in each assessment consisted of dichotomous answers which precluded factor analysis to establish construct validity. However, the nature of the test construction implies face validity (AssessmentDay, 2015). While the instrument has limited validity, it offers functional potential.

Reliability

Reliability testing was possible because only dichotomous items were chosen from the question pool. The Kuder-Richardson Formula 20 was used to calculate the internal consistency

reliability of all 60 questions on a scale of zero to one. The Kuder-Richardson Formula 20 is designed to test reliability of instruments where only two answers are possible. The result of testing the participant data was a reliability coefficient of .371, on a scale of zero to one where higher values indicate higher reliability (Heale & Twycross, 2015). The result implies limited consistency in the way the students responded to the questions.

The Kuder-Richardson coefficient can be altered if unreliable questions are discovered and removed from the test. The individual item analysis was procured through the SPSS reliability testing feature. The data are displayed in a table generated by SPSS that shows each item and the Kuder-Richardson score without that item. There was a range of .332–.406 for the change in the Kuder-Richardson coefficient if that item were deleted; indicating that removal of any single item would not greatly alter the internal consistency reliability. Therefore, none of the items were removed.

Summary of the Results

This quasi-experimental design sought to examine the potential relationship between the use of case studies as a teaching method and the development of critical thinking skills in high school students. There was a statistically significant difference between the three levels of factor one, i.e. students' critical thinking test scores over time one, two, and three. There was not a statistically significant difference between two levels of factor two, i.e. the test scores between the case study group and the non-case study group until the third assessment. There was a statistically significant interaction effect between the two-factor level combinations, i.e. the groups and the time the tests were taken.

There were five potential internal validity threats: history, maturation, selection, testing, and mortality (Creswell, 2014). The passing of time and the maturity differences between 14-

year-old students and 17-year-old students posed a moderate threat. The original testing windows were extended from three days to five days to allow for more flexibility for both students and teachers to stay on track. The time extension did add the complication of pushing the study close to end of the school year and created an overlap with the state standardized testing window by the conclusion of the study.

The threats of selection, testing, and mortality were mitigated in several ways. Although none of the teachers were skilled in CBT, some were more amiable to incorporating CBT than others. The participating teachers were provided two 20-minute training sessions on incorporating case studies into classroom instruction. The two teachers randomly chosen to represent the non-case study group expressed relief at the prospect of not having to change any lesson plans or teaching strategies. Conversely, at least three of the teachers in the case study group were positive about the prospect of incorporating case studies into their lessons. In regard to the testing threat, some of the students expressed interest in their test results and kept track of their progress. However, a major concern was the students' attitude toward the testing, which will be discussed in chapter five. Finally, the concern of mortality was mitigated by the fact that none of the teachers dropped out and only 13 of the students dropped out due to lack of interest or inability to take a test within the testing window.

There were three unforeseen limitations encountered as the study progressed. The first was the unequal numbers of participants in the non-case study group compared to the case study group. This was the result of randomly selecting the teachers for the non-case study group prior to the completion of the student recruitment process. Additionally, one teacher recruited most of the participants in the non-case study group. The second was the effect of conducting the study so close to the end of a school year. This meant the study protocols overlapped with the state

standardized testing window, shortened class periods, and potentially decreased student motivation. The third, was that three teachers that took advantage of the provided case studies, answer keys, and teaching notes; the others created or found case studies to incorporate. This may have created some discrepancies between teachers in the degree to which case studies were implemented. A post-experiment debrief interview or survey may have provided insightful information into the degree of implementation for each class.

Data Analysis

Preparing the Data for Analysis

Data collected were entered into an Excel spreadsheet. Each participant's item level data was recorded across a set of 60 rows. The rows are divided into the three 20-questions assessments. One was used to indicate a correct answer and zero to indicate an incorrect response. The rows of data from the case study group are listed first and were coded with a one, followed by the data listed from the non-case study group, which were coded with a two. Any data from a participant who did not complete all three tests was removed. Once the data were prepared, it was imported into the Statistical Package for the Social Sciences.

Five basic assumptions relevant to this study needed to be met to justify the repeated measures ANOVA: no extreme outliers, normality, homogeneity of variances, homogeneity of covariances, and sphericity (Laerd Statistics, 2015). Two tests for outliers, the univariate test using the interquartile range rule of three in SPSS revealed no outliers (Hoaglin & Iglewicz, 1987), and the multivariate Mahalanobis Distances test ($p = .01$, $df = 3$, chi square critical = 16.27) showed no outliers. Performance on the assessments was normally distributed ($p > .05$) except for the mid-point assessment ($p = .019$), as assessed by the Shapiro-Wilk's test of normality. The normality assumption was further tested inspecting histograms and $p-p$ plots

rendered with SPSS, which indicated a normal distribution (White, 2013). The homogeneity of variances assumption was met, based on Levene's test of homogeneity of variance ($p > .05$). Box's test of equality of covariances matrices indicated homogeneity of covariance ($p = .720$). The results of Mauchly's test for sphericity showed that the assumption was met for the two-way interaction $\chi^2(2) = 2.8, p = .245$. Having met the assumptions, the results of the hypotheses testing using the RM ANOVA are discussed in the following section.

Detailed Analysis

This research study sought to answer the question: Will students taught using the directed case study method have higher mean score on a series of critical thinking assessments compared to students taught using the teacher-centered method?

1. **Results of Hypothesis 1:** The mean test scores on critical thinking assessments One, Two, and Three will be equal regardless of group (no main effect for the time factor over three levels).

The mean scores from both groups showed decline in critical thinking scores over time. The mean scores of the case study group show a slight decline over the course of the three critical thinking assessments. The mean scores of the critical thinking assessment for the non-case study group decline more sharply over the course of the three critical thinking assessments. The means of the critical thinking assessment for both groups are presented in Table 6.

Table 6

Students' Mean Scores on the Three Critical Thinking Assessments.

	<i>n</i>	Assessment 1 <i>M(SD)</i>	Assessment 2 <i>M(SD)</i>	Assessment 3 <i>M(SD)</i>
Case study group	62	11.7 (2.2)	11.2 (2.2)	10.9(3.1)
Non-case study group	17	12.4 (2.4)	10.9 (2.5)	9.1(2.5)
Total participants	79			

The scores of the three assessments at factor one (time) were compared at three levels (Time One, Time Two, Time Three). The assessment scores were not equal over time, and the difference was statistically significant $F(2,154) = 9.34, p < .001$. The use of partial eta squared (η_p^2) specified an effect size of 10.8%, indicating that the use of the directed cases studies likely contributed to the differences between the test scores. The comparison of the assessment scores over time are presented in Table 7.

Table 7

Comparison of Students' Assessment 1 Scores, Assessment 2 Scores, and Assessment 3 Scores

Source		Type III Sum of Squares	<i>Df</i>	Mean Square	<i>F</i>	Sig.	Partial eta squared	Observed power ^a
Time	Sphericity assumed	114.9	2	57.5	9.34	.000	.108	.977
Error (Time)	Sphericity assumed	947.7	154	6.15				

a. Computed using alpha = .05

The results indicated that the scores on the critical thinking assessments were not equal over time, therefore the null hypothesis was rejected. This indicates that there was a change in factor one, i.e. the students' performance on the critical thinking assessment over the course of time.

Results of Hypothesis 2: The mean test scores on the critical thinking assessment of the students instructed using directed case studies will be equal to the mean test scores of students instructed using teacher-centered methods (no main effect for the group factor over two levels).

The scores of the three assessments at factor two (groups) were compared two levels (case study group and non-case study group). The assessment scores were not statistically significantly between the groups $F(1,77) = 1.7, p = .200$. However, the post hoc test comparisons did add some additional information. There was no difference in the non-case study ($M = 11.8, SD = 2.2$) compared to the case study group ($M = 12.3, SD 2.4$) at the beginning (pre-test) of the trials, $F(1,77) = .82, p = .368$. The critical thinking assessment scores were not statistically significantly different between the non-case study group ($M = 10.9, SD = 2.51$) and the case study group ($M = 11.2, SD = 2.18$) at the mid-point assessment, $F(1,77) = .21, p = .646$. There was a statistically significant difference between the critical thinking assessment scores between the non-case study group ($M = 9.05, SD = 2.5$) and the case study group ($M = 10.9, SD = 3.1$) at the final test $F(1,77) = 5.34, p = .024$. The pairwise comparisons between the scores of the three assessments are shown in Table 8.

Table 8

Statistical Comparison Between the Mean Scores of the Case Study Group and the Non-Case Study Group for the Three Assessments.

Assessment		Mean difference	Std. error	Sig. ^b	95% Confidence interval	
					Lower bound	Upper bound
1	2	.99	.43	.075	-.07	2.0
	3	2.1	.50	.000	.85	3.3
2	1	-.99	.43	.075	-2.1	.07
	3	1.1	.51	.103	-.15	2.3
3	1	-2.1	.50	.000	-3.3	-.85
	2	-1.1	.51	.103	-2.3	.15

Based on estimated marginal means.

^bAdjustment for multiple comparisons: Bonferroni

Despite this difference, the null hypothesis that mean test score will be equal between the groups is not rejected.

Results of Hypothesis 3: There is no difference in the mean scores on the critical thinking assessment for any factor level combination (no interaction effect).

The results indicated a statistically significant interaction between factor one (time) and factor two (groups) $F(2, 154) = 3.33, p = .039$, partial eta squared (η_p^2) = .041. The critical thinking scores were different because of the use of case studies over the course of time. The results of the interaction effects are presented in Table 9.

Table 9

The Effect of Case Studies on Students' Scores on the Three Critical Thinking Assessment

Source		Type III sum of squares	Df	Mean square	F	Sig.	Partial eta squared	Observed power ^a
Time * Group	Sphericity assumed	40.9	2	20.5	3.33	.039	.041	.622
Error(Time)	Sphericity assumed	947.7	154	6.15				

a. Computed using alpha = .05

The mean scores of the non-case study group decreased from the pre-test ($M = 12.3$, $SD = 2.42$) to the mid-point test ($M = 10.9$, $SD = 2.51$) and continued to decline at the post-test ($M = 9.05$, $SD = 2.53$). The mean scores of the case study group also decreased over the course of the testing intervals, but not as dramatically $M = 11.79$, $SD = 2.22$; $M = 11.22$, $SD = 2.18$; $M = 10.94$, $SD = 3.08$, respectively. The use of partial eta squared revealed a slightly less than moderate effect size. The partial eta squared index denotes that four percent of the variance in critical thinking test scores was the result of the use of case studies. The null hypothesis that there is no interaction effect was rejected. The change in mean scores over time are illustrated in Figure 2. The slope of both groups trends downward, but the slope of the non-case study group declines more steeply as the study progresses. This indicates the effect of the interaction, demonstrating that students' critical thinking assessment scores were dependent on the use of directed case studies.

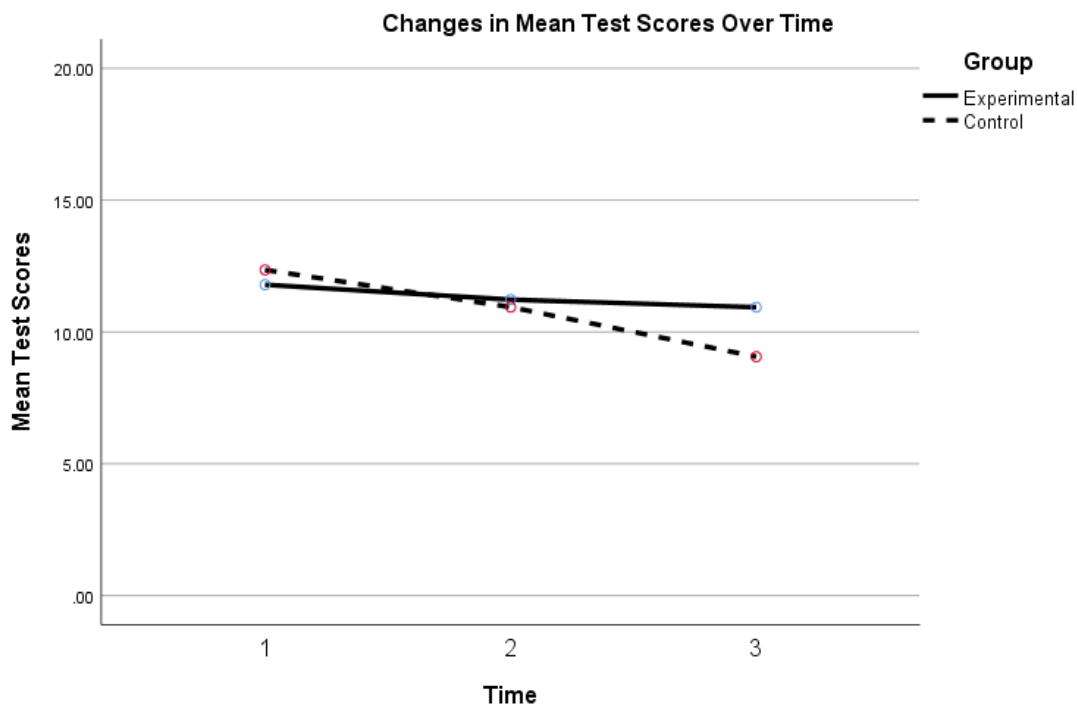


Figure 2. Changes in both groups' mean test scores over time.

Summary

The study sought to evaluate the effect of case studies on the critical thinking skills of high school students. The participants included 9th and 10th grade biology students from a large, semi-urban high school. Seven biology teachers and 79 students participated in the study. The study consisted of a non-case study group ($n = 17$) and a case study group. Both groups took a critical thinking pre-test, a mid-point test, and a post-test. The test scores were analyzed using a repeated measures ANOVA design. The data had to meet some basic assumptions to proceed with the statistical analysis.

There were no outliers, as assessed by boxplots and the multivariate Mahalanobis Distances test. The data was normally distributed, based on the inspection of histograms and Shapiro-Wilk's test of normality ($p > .05$). There was homogeneity of variances ($p > .05$) as

assessed by Levene's test of homogeneity, and covariances ($p > .05$) based on Box's M test. The sphericity assumption was met based on Mauchly's test for sphericity for the two-way interaction $\chi^2(2) = 2.8, p = .245$. The scores of the three assessments at factor one (time) were compared at three levels (Time 1, Time 2, Time 3) and showed a statistically significant difference $F(2,154) = 9.34, p < .001$. The scores of the three assessments at factor two (groups) were compared at two levels (case study group and non-case study group) and showed a significant difference only between the scores of the non-case study group ($M = 9.05, SD = 2.5$) and the case study group ($M = 10.9, SD = 3.1$) at the final test $F(1,77) = 5.34, p = .024$. There was a statistically significant interaction between the groups students were in and the time of the test $F(2, 154) = 3.33, p = .039$, partial eta squared (η_p^2) = .041. The explanations and extensions based on these findings will be discussed in Chapter Five.

Chapter 5: Discussion and Conclusion

Avery's dilemma of trying to discover effective instructional methods that fit her specific educational goals is not uncommon. Many educators find themselves looking for reliable instructional methods that are both efficient and effective, but also fit into their personal philosophy of education. Discovering the strengths of instructional methods requires both qualitative and quantitative research efforts. This quasi-experimental study sought to identify whether the directed case study teaching method had a quantifiable impact on the critical thinking skills of high school biology students. The intent of the quantitative nature of the study was to use critical thinking test scores as an objective measure of the effectiveness of CBT in the specific area of critical thinking. This information may provide an indication of the functionality of the directed case study method in the classroom.

Apart from the main purpose of the research, this dissertation offers a unique study design. Kaplan (1964) and Maslow (1966) observed the tendency toward using one methodology to approach research questions when they postulated the *Law of the Instrument*. The propensity to use pre/post testing can be observed throughout education research. Alternatively, the repeated measures design is a helpful tool for clarifying the utility of any teaching method over time. The repeated measures analysis provides additional information into changes over time, and potentially detection of the extraneous factors common to quasi-experimental conditions (Adams & Lawrence, 2015; Best & Kahn, 2006). Typical pre-test and post-test design provides information about the start and finish only, leaving speculation as to what transpired along the way. Following the repeated measures design can fill in this information gap to generate a clearer picture of the phenomenon under investigation (Ellis, 1999). Research along these lines can assist teachers in making methodological decisions.

This research study addressed the question of whether the directed case study method increased the critical thinking skills of 9th and 10th grade biology students. The intent was to compensate for the deficiency of quantitative case study research discovered in the literature. The study would augment the literature discussing the efficacy of case-based teaching and the role of methodology in facilitating critical thinking in high school students.

The literature review emphasized that active learning methods facilitate the development of critical thinking skills. The use of active learning methods, such as CBT and PBL, are characteristic of a constructivist paradigm. Thus, constructivist theory undergirds the study by providing a conceptual framework upon which to build. In short, constructivist theory is the idea that learners build on previous knowledge (Schmidt, et al., 2017). Specifically, CBT ties new information to prior knowledge through relatable stories. The story frames the problem, and provides a context for new information or applications. The systematic approach to researching the problem presented in the story, and the application of knowledge in novel ways, is thought to develop critical thinking skills.

Experientially, both teachers (Herreid, 2011) and students (Klegeris & Hurren, 2011) enjoy the use of CBT methods. While the novelty of the method may play a role, the most commonly cited reasons for adopting CBT are relevance and the interest the story generates (Herreid, 2011). Regardless of how a teaching method is perceived, the question of efficacy remains. The difficulty is determining how to measure efficacy.

This study sought to test the claim that active learning builds critical thinking skills through an empirical, quantitative study. The literature review revealed a substantial lack of quantitative research tying critical thinking to CBT, notwithstanding the observational, anecdotal, and qualitative assertions. Contributing empirical data, along with an elegant,

repeatable, quasi-experimental study design not only buttresses the qualitative side of the body of research, it also paves the way for further studies to investigate which methodologies best enhance critical thinking in high school students. The thought flow of this chapter seeks to (a) discuss the results of the data analysis, (b) consider how the results connect to the literature, (c) apply the implications of the results to the field of education, and (d) suggest recommendations for additional research studies.

Summary of the Results

Critical thinking skills are one of the hallmarks of the modern education movement (Barak, Ben-Chaim, & Zoller, 2007; Bilica, 2004; Conley, 2010). As such, critical thinking is considered a 21st century skill; the reason that it is important is because the job market is constantly changing. The rote and repetitious skills of the assembly line are giving way to careers featuring adaptability and innovation (Knight & Marciano, 2013). Students need skills that are adaptable in the face of changing workforce demands (Greenstein, 2012; Griffin, & Hesketh, 2003; Lauer, 2005). Methodologies that consistently promote CT are a premium choice for future thinking educators. Often, these methodologies are rooted in constructivist theory.

Constructivist theory emphasizes the importance of students learning to investigate and inquire on their own (Prince & Felder, 2006). This student driven approach to problem solving is thought to increase critical thinking (Herreid, 2004). CBT is one active learning method where students can hone problem solving skills (Kulak & Newton, 2015). CBT features real-world problems, so the topics are relevant (Kesner, Hofstein, & Ben-Zvi, 1997; Pai, 2009). Both relevance and active learning contributes to increased student motivation (Centin-Dindar, 2016; Wolter, Lundeberg, & Bergland, 2013). CBT is an active learning methodology rooted in constructivist theory.

The potential value of incorporating case studies into instruction is threefold. First, Herreid (2005) described case studies as learning with a story. The story sparks the interest of the students and puts the learning into a context, answering the question, “Why?”. Second, Cliff and Curtin (2000) attested to the value of using case studies as a viable active learning strategy in content heavy classes. This potentially alleviates the tension between covering content, and active learning. Third, several authors alluded to the possibility that CBT not only improved comprehension, but also enhanced critical thinking (Kek & Huijser, 2011; Popil, 2010, Tiwari & So, 2006; Woody, Albrecht, Hines, & Hodgson, 1999). These potential benefits of CBT compel verification through research.

Research Approach

The question guiding this study was: Does the directed case study teaching method increase critical thinking skills in 9th and 10th grade biology students? A quasi-experimental design was employed to investigate the research question. The study compared a non-case study group and experimental group using a repeated measures design (Creswell, 2014). A pretest was administered to establish a baseline for both groups, followed by a mid-point assessment and then a post-test. Over the six-week period the case study group experienced two iterations of the directed case study method; one prior to the midpoint test and one after the midpoint test. The scores of the tests were averaged and compared using a repeated measures ANOVA and post-hoc tests to determine if there was a significant difference in the scores (Ellis, 1999). There were 79 participants ($n = 79$), 62 in the case study group and 17 in the non-case study group. The participants were scattered throughout the class periods of seven biology teachers. There were three null hypotheses tested:

Null Hypothesis 1: The mean test scores on the critical thinking assessments One, Two, and Three will be equal regardless of group.

Alternative Hypothesis 1: The mean test scores on the critical thinking assessments One, Two, and Three will not be equal regardless of group.

The intent of this hypothesis was to analyze the change occurring in each group separately over time. There was no difference in the case study group over time, however, the non-case study group showed a significant difference in scores over time $F(2,154) = 9.34, p < .001$. In other words, the scores of the case study group remained relatively constant, while the scores of the non-case study group fell.

Null Hypothesis 2: The mean test scores on the critical thinking assessment of the students instructed using directed case studies will be equal to the mean test scores of students instructed using teacher-centered methods.

Alternative Hypothesis 2: The mean test scores on the critical thinking assessment of the students instructed using directed case studies will not be equal to the mean test scores of students instructed using teacher-centered methods.

The intent of this hypothesis was to compare the difference in the test scores between the two groups. The scores of the two groups were not statistically different at time one or time two. There was a statistically significance difference between the groups at time three $F(1,77) = 5.34, p = .024$. To clarify, the scores of Tests One and Two were statistically similar between the groups, but the score of Test Three was statistically different.

Null Hypothesis 3: There is no difference in the mean scores on the critical thinking assessment for any factor level combination.

Alternative Hypothesis 3: There is no difference in the mean scores on the critical thinking assessment for any factor level combination

This hypothesis was the main focus of the research study. There was an interaction effect between the directed case study and critical thinking scores $F(2, 154) = 3.33, p = .039$, meaning that the scores of the critical thinking tests were different because of the use of case studies over time. While neither group showed an increase in test scores, the non-case study group's mean scores decreased more dramatically over time.

Discussion of the Results

Does the directed case study method improve the critical thinking skills of high school biology students? The answer to this question is contingent upon the answer to the three subordinate hypotheses. Each of these three hypotheses will be discussed in order.

Hypothesis 1

The first hypothesis focused on the changes occurring within each group individually over time. There was no statistical difference between scores on tests One, Two, and Three for the case study group—that is, that the scores remained consistent over time. However, there was a statistically significant difference between the scores on Test One and Test Three $F(2,154) = 9.34, p < .001$ for the non-case study group. The non-case study group showed a difference between the scores on Test One and Test Three. This finding indicates that other factors that may have influenced test scores of students in the non-case study group. At the outset of the study, the researcher expected that the scores of the non-case study group would remain relatively consistent over time. Study data showed decreases in scores among the non-case study group over time, with the range of scores differing between tests One, Two and Three (five to 17, six to 17, and three to 18 respectively).

One possible explanation for the decrease in scores among the non-case study group is that student motivation decreased as the school year ended. Dyck (2013) describes the shifting attention from the current year to the next year as a possible explanation for diminishing student motivation toward the end of the school year. Paterson (2018) suggested that the slump in student effort as the school year winds down is the result of anticipating the summer break. Regardless of the cause, reduced motivation can harm student performance.

Another explanation is that the tests increased in difficulty through the question vocabulary, wording, or stem topics. This line of inquiry was pursued to some extent, and the results indicated that the reading level did not get progressively harder. The three tests were analyzed for difficulty based on the sentence length and word length (Flesch, 1948). The results were 55 out of 100 on Assessment One, 52 on Assessment Two, and 55 on Assessment Three according to the Flesch Reading Formula. Text that scores in the 50 to 59 range is considered “fairly difficult” to read because the text should be understood by 10th graders (Flesch, 1948). Nevertheless, reading difficulty is not the same as question difficulty, which is difficult to gauge with dichotomous questions.

Another possibility is that using raw score data skewed the test results of non-case study group subjects. When using raw score data, test difficulty can misrepresent results. Dimitrov and Rumrill (2003) argued that difficult test items misrepresent the growth in high-performing students while easier test items show greater gains in low-performing students. While raw score data may present some difficulties, it is a relatively straightforward method used to measure progress.

Hypothesis 2

The second hypothesis focused on the difference in the test scores between the two groups. The scores of the two groups were not statistically different at test one or test two. There was a statistically significance difference between the groups at test three $F(1,77) = 5.34, p = .024$. To clarify, the scores of tests One and Two were statistically similar between the groups, but the score of Test Three was statistically different. Taken together however, the overall comparison between the groups was not statistically significant $F(1,77) = 1.7, p = .200$.

The first test provided a baseline comparison for the groups. The statistical equivalence of the test scores for test one indicates that both groups began the study at the same starting point. After the first iteration of the case studies, the two groups were still scoring the same on the critical thinking test. By the end of the second iteration of the case study treatment, the scores of the non-case study group had dropped enough to show statistical significance.

Hypothesis 3

There was a statistically significant interaction effect between case study teaching and critical thinking test scores $F(2, 154) = 3.33, p = .039$, partial eta squared (η_p^2) = .041. Despite the presence of a statistical difference in mean scores, it must be taken into consideration that the mean scores of both groups were decreasing. The means of the case study group were: Test One: $M = 11.79, SD = 2.22$; Test Two: $M = 11.22, SD = 2.18$; Test Three: $M = 10.94, SD = 3.08$. The means of the non-case study groups were: Test One: $M = 12.3, SD = 2.42$; Test Two: $M = 10.9, SD = 2.51$; Test Three: $M = 9.05, SD = 2.5$. Even though the case study group did not decrease as rapidly as the non-case study group, both groups saw a decline in mean critical thinking test scores over time.

There was an interaction effect $F(2, 154) = 3.33, p = .039$. The case study group did not show the same dramatic decline in mean test scores as the non-case study group. This finding rouses the possibility that case studies have the potential of holding a students' interest as the end of the school year approaches. This potential finding is consistent with the well documented benefit of active learning on student motivation (Bailey, 2008; Flynn & Klein, 2001; Maudsley & Strivens, 2000). Another possibility is that CBT encourages students to use a systematic approach to problem-solving and perhaps better equip students to handle more difficult test items (Gijbels, Dochy, Van den Bossche, & Segers, 2005). However, the data does not support either explanation conclusively.

Discussion

Implementation of quasi-experimental study designs is difficult in the public-school setting (Best & Kahn, 2006). Nonetheless, this study endeavored to address the need for empirical and quantitative research into the efficacy of the directed case study method (Bilica, 2004). Results may have been influenced by factors including study design, timing, and participant factors, each of which may have exerted influence independently or in combination with other factors. One design factor that may have influenced the results of this study was the imbalance in numbers between the non-case study group and the case study group. While nonequivalent groups are less than ideal, the results may be cautiously interpreted (Best & Kahn, 2006). The selection of the teachers was random, but the teachers were chosen prior to the completion of the recruitment process. Each time a teacher was chosen for a study group, that teacher brought into the study all the potential general biology students in their schedule. Once the number of potential participants was nearly equal, the selection process stopped. However, this resulted in an unbalanced design, because the number of students recruited from each

teacher's schedule was between one and 27. When one of the non-case study group teachers only recruited a single student, that meant the clear majority of students in the no case study group were assigned to the classes of one teacher. Had the selection of the groups been postponed until after the recruitment process, the teachers would have had less time to prepare the case study lessons prior to the start of the study.

Another potentially confounding design issue revolved around the testing instrument's reliability and validity. This was an issue because there was little available information on the reliability or validity of the instrument until it was used to collect data. One of the experimental goals was to analyze the critical thinking instrument for reliability. Reliability estimates indicate how consistently an instrument measures a construct (Kimberlin & Winterstein, 2008). Pilot testing the instrument on a small sample could have specified the reliability according to the Kuder-Richardson Formula 20 (Heale & Twycross, 2015). The results of pilot testing may have provided additional information that would have influenced the final decision to use the open access AssessmentDay critical thinking instrument. The instrument was accepted based on face validity, since the dichotomous answers precluded factor analysis, and other forms of validity testing were unavailable. Validity is a measure of how well an instrument measures the construct it is supposed to measure, which is contingent upon using the instrument to measure the intended construct (Kimberlin & Winterstein, 2008). While the AssessmentDay critical thinking instrument had relatively low reliability and validity, the alternatives were using an expensive instrument, modifying an existing instrument or constructing a new instrument. Constructing or modifying an instrument would also require reliability and validity testing (Kimberlin & Winterstein, 2008). Balancing practicality, availability, functionality, and the expense of an

instrument made for a complex decision process. Therefore, careful consideration of these factors should be taken when choosing a testing instrument.

One significant timing related factor may have been the time of year that the study took place. The final iterations of the testing took place the last month of the school year. During that same month the biology students were subjected to classroom diagnostic tests, Keystone Exams, and finals. These are three intensive standardized tests. The third critical thinking test administration overlapped with Keystone Exams. Keystone Exams are the state mandated standardized tests in algebra, literature, and biology administered to 9th and 10th grade students. These Keystone Exams took place the first two hours of each school day over the course of a week. The extensive testing during the final month of school may be one explanation for the drop in the scores at time three. Sievertsen, Gino, and Piovesan (2016) found that standardized test scores tend to decrease throughout the school day because of cognitive fatigue. A decline in performance because of mental exhaustion is a possible explanation. However, the case study group also experienced the testing during the last month of school and maintained their average score.

One might suspect the number of students involved or factors involving teacher demographics may have influenced the results. The most significant student factor was the sample size. A larger sample size would be desirable, especially if the participants better represented the demographics of the school. Sample size is typically determined with an *a priori* power analysis (Length, 2001). An *a priori* power analysis for a two-factor repeated measures ANOVA with 95% explanatory capability and the moderate effect size of .25 yielded a sample size of 142 students. This study recruited a sample size of 79. Button et al., (2013) recognized the significance of sufficient statistical power in research, and that replicating a low power study

may require a larger sample size than the original. Increasing the sample size has the benefit of avoiding the mistake of not rejecting the null hypothesis when the null hypothesis is false.

The pertinent teacher concerns were implementation fidelity and balancing the teacher demographics. The degree of implementation is difficult to control (Hmelo-Silver, 2004; Pedersen, 2003; McFarlane, 2015; Schmidt, Van der Molen, Te Winkel, & Wijnen, 2009). Requiring teachers to use the same case study was impractical, because the teachers were at different places in the curriculum. Besides the impracticality, Kesner, Hofstein & Ben-Zvi (1997) found that allowing teacher choice of topic had the benefit of improving teacher perceptions toward using a new teaching strategy. Nevertheless, using the directed case studies in a more standardized way may have proven advantageous. The teachers in this study were encouraged to use the case studies along with the teaching notes from the NCCSTS repository. Three of the seven teachers involved took advantage of this resource. The others preferred to either find or create their own. Providing an outline of expectations or a checklist might have helped to better align implementation. A follow up survey of the teachers would have provided some voluntary qualitative data to evaluate adherence to the implementation protocols.

There were two potentially influential teacher demographic factors that could have shaped the outcome. The first was the difference in teacher experience between the non-case study group and the case study group. Klegeris and Hurren (2011) recognized that multiple teachers in an experiment introduces bias due to differences in teaching abilities. The second is the variety of teachers in each group. Best and Kahn (2006) recommended equalizing as many variables as possible between the control and experimental groups but acknowledge that eliminating some variables reduces the ability to generalize the study to a wider population. The non-case study group consisted of two teachers, one male and one female, both with over 20

years of experience. Whereas the case study group consisted of five teachers, two males and three females, with a wide range of teaching experience. Extraneous factors should be controlled as much as possible, because of their potential to influence the outcome (Creswell, 2014). However, quasi-experimental research in the public-school setting is often subject to unanticipated extraneous factors.

In summary, several different dynamics could have prejudiced the findings. The three categories of counterclaims include design of the study, timing, and participant issues. The design topics related to the imbalance between the groups and the instrument selected. The timing discussion revolved around the hectic testing at the end of the school year and the decline in student motivation. The smaller than desired sample size, possible implementation discrepancies, and teacher demographics rounded out participant concerns. Mitigating these factors would strengthen a future study.

Discussion of the Results in Relation to the Literature

CBT is not a silver bullet for problems facing the education system. Nor could this study have confirmed that directed case studies will undoubtedly increase critical thinking skills in high school science students. Case-based teaching however, may offer a relevant method that sets a context for learning (Fossey & Crow, 2011). As Preszler (2006) observed, “whereas lectures and textbooks may be an efficient method of presenting knowledge, most students need additional activities to process the information presented in lecture” (p. 21). The intellectual activity required to think through information requires problem-solving, skepticism, and analysis (Herreid, 2004; Kek & Huojser, 2011). Directed case studies may be a method that is useful for honing those skills. Additionally, case studies take the process one step further by applying knowledge, especially to new situations (Flynn & Klein, 2001). The inconclusive results of this

study do not discredit the potential intellectual benefits of the directed case study teaching method. Rather, the study is consistent with the assertion in the literature that CBT sustains critical thinking by encouraging student motivation. The findings of this dissertation suggest that critical thinking assessment scores were related to the use of directed case studies. This finding is, at minimum, compatible with the literature that affirms the relationship between critical thinking skills and the use of CBT (Flynn & Klein, 2001; Hager, 2004; Herreid, 2004; Lauer, 2005; Nava-Whitehead, Augusta, & Gow, 2011; Noblitt, Vance, & Smith, 2010; Yadav et al., 2007). The reasons seem to revolve around active student engagement and student motivation.

The Role of Active Learning

First, consider the role of active student engagement and critical thinking. Tiwari and So (2006) observed that traditional didactic instruction is passive for the learner, while the alternative is for the student to think critically. This juxtaposition between student passivity and active, critical engagement is noteworthy because it hints at the necessity to deliberately involve the mind in critical thinking. Specifically, Maudsley and Strivens (2000) observed that critical thinking can be taught if the teaching “*consciously* aims to develop thinking strategies by providing encouragement, opportunities, and guided practice involving principles and techniques” (p. 540). To foster CT, the teaching style or methodology should be intentional about stimulating student involvement. Lai (2011) echoed this viewpoint by proposing that development of critical thinking skills results from engaging in learning. Therefore, if active student engagement is an integral part of developing critical thinking, and the directed case study method involves active learning there would be a connection that may offer a plausible explanation for the results of this study.

The Role of Motivation

The results of this study may support the assertion that CBT can sustain student motivation and interest as the school year ends. The connection between active learning methods and student motivation is a reoccurring theme in the literature (Bailey, 2008; Cliff & Wright, 1996; Flynn & Klein, 2001; Hmelo-Silver, 2004; Maudsley & Strivens, 2000). CBT falls under the umbrella of active learning methods because student involvement through investigating, questioning, and researching is required. Primarily, active learning cultivates intrinsic rather than extrinsic motivation because of the pragmatic approach of building knowledge for the purposes of solving a problem or decision making (Pedersen, 2003). Coupling clear and purposeful learning with problems relevant to students' interests or career paths fosters intrinsic motivation (Pedersen, 2003). Case studies are an instructional method that instructors can use to help stimulate student motivation through relevant, purpose driven problem-solving (Wolter, Lundeberg, & Bergland, 2013). The use of the directed case study method may prove advantageous for keeping students mentally engaged amid times when student motivation tends to fall.

Limitations

Limits of this study include its non-random groups, participant demographics, timing, evaluation instrument, and the fidelity of participant teachers' implementation of CBT. Each limitation will be elaborated upon in the following paragraphs, along with suggestions for strengthening the research design. Although the outcomes of this study were not as expected, the study provides a framework that could be built upon in future research efforts.

Quasi-experimental designs are a well-established research technique in education settings. However, one inherent limitation of quasi-experimental research in education settings is

the non-random grouping of students (Best & Kahn, 2006; Creswell, 2014). Non-randomization of the participants may lead to undetected confounding variables. Not only were students in this study grouped non-randomly, the control and experimental groups were unequal in size. Equalizing the groups would have strengthened the research design. Matching the study groups by teacher experience and other demographics would have eliminated some variables. Finally, increasing the sample size to at least 142 would have increased the statistical explanatory power of the study.

The second limitation was the demographics represented by the study. The study was limited to 9th and 10th grade general biology students in a large semi-urban high school. The findings should not be generalized to education settings beyond this scope. Repeating the study across a variety of high schools with different demographics would allow some generalizability, along with incorporating honors level students for comparison. Study timing was the third limitation. The timing limitation had two aspects. One was that the study took place at the end of the school year. Results may have varied were the study replicated at another time in the school year. The other aspect of the timing limitation was the length of the study, which was only six weeks. Perhaps more iterations of case studies would have provided the time necessary to for students develop critical thinking skills. Fourth, part of the study was to investigate the potential use of the AssessmentDay open access critical thinking assessment. The use of the AssessmentDay test required that the test not be modified. Piloting the testing instrument would have been advantageous to establishing the reliability. Creating a new instrument with several answers to each item that would allow factor analysis and validity testing would be helpful to future studies. Other critical thinking measures are available but incur an expense.

Finally, the degree of implementation limits the study. As Dochy et al. (2003) have observed, there is a wide spectrum of possible implementation of CBT from the lesson level to the curriculum level. While curriculum revision to include CBT might yield a profound effect on learning outcomes, experiments that are smaller in scope may be more manageable to conduct. Insisting on using case studies found on the NCCSTS website would create more consistency in approach. There are at least three potential protocols that could have improved implementation standardization. Fidelity of implementation could be gauged against the lesson plans provided by NCCSTS or a checklist of expectations. Moreover, observing the teachers throughout the study could have provided qualitative data about the degree of implementation. Finally, A post-study survey of the teachers could provide some indication of the degree the directed case studies were implemented. The survey could also supply some qualitative feedback about the efficacy of the directed case study method, the critical thinking instrument, and the research design.

Implications of the Results for Practice, Policy, and Theory

CBT is an instructional paradigm that has been adapted from teaching methods used in legal and medical education for use in other disciplines (Fosset & Crow, 2011; Herreid, 2005). Proponents of CBT take a constructivist view, emphasizing that learning should be active, investigative, and inquiry based. Students should construct their understanding through experimentation and building on prior knowledge (Antepohl & Herzig, 1999). The most noteworthy claim in the relevant literature is the potential effect of CBT on critical thinking. This study failed to prove that CBT could enhance high school students' critical thinking. However, declines in critical thinking scores in the case study group were less than in the non-case study group. Therefore, the connection between the directed case study method and critical thinking should not be dismissed. Given the emphasis on critical thinking in standards such as the

Partnership for 21st Century Skills, Common Core State Standards, and Next Generation Science Standards, educators must find strategies to develop students' critical thinking skills. Lai (2011) related the thematic importance of critical thinking in an education literature review. Noting recent education reforms in many countries designed to develop students' critical thinking, Barak, Ben-Chaim, and Zoller (2007) investigated instructional methods that promote critical thinking. The correlation between students' critical thinking skills and educational outcomes underscores the need to discover techniques that foster critical thinking.

Another attractive aspect of the directed case study method is that it offers educators a stepping stone from teacher-centered didactic instruction toward an active learning approach. The effectiveness of the directed case study method in improving students' critical thinking skills was not proven conclusively through this study. However, teachers who participated in this study may have seen the value of the problem-solving, analysis, and reasoning required by students wrestling with a case study dilemma (McFarlane, 2015). In CBT, educators utilize characteristics of active learning along with the inquiry, relevance, and application intrinsic to the story to spark student interest. The primary benefit of this approach is in crafting scientific thinkers (Lauer, 2005). However, an emphasis on critical thinking requires a theoretical shift in the purpose of education; from an emphasis on rote memorization, facts, and knowledge toward equipping students with the intellectual tools to problem-solve and apply their knowledge. Nava-Whitehead, Augusto, and Gow (2011) warned that "too often we [teachers] place emphasis on what we want students to know rather than proficiencies we want them to develop, such as the ability to think critically, problem-solve, and work collaboratively in groups" (p. 65). The directed case study method allows teachers to engage students actively in becoming more scientific thinkers, as opposed to the traditional dissemination of scientific details.

Another congruent line of application to educational practice and theory is prompting teachers to reflect on the relevance and applicability of curriculum content. If case studies offer real-world problems, mysteries, and stories that require the same application of knowledge and skill set students need to be successful in their chosen career field, then the purpose of the lesson may become clear. Wolter, Lundberg, and Bergland (2013) stressed the importance of educators making science relevant to students in at least three ways: using science to solve real-world problems, developing skills needed for a future occupation, and understanding how things work in the natural world. While the first two may be appealing to individuals who already have an interest in science, the third has the wider, more general, lure of curiosity. Stimulating a student's curiosity can be a powerful motivator (Wolter, Lundberg & Bergland, 2013). Regardless of which mechanism is used to keep the learning relevant, the main thing is to accentuate the connections between the information presented and its authentic application. Cliff and Wright (1996) concurred, "The cases are given to provide real-world relevance or to enhance motivation for continued learning of the scientific facts and figures" (p. 24). In summary, this research may at least induce some educators to reflect on curriculum in terms of relevant application and methodologies that are conducive to that delivery.

Thirdly, educators may recognize the value of a systematic approach to problem-solving and incorporate it into their regular practice. This was a central theme throughout this dissertation, and central to the implementation of the directed case studies. Hmelo-Silver (2004) enumerated a multi-step process of problem-solving that includes clearly representing the problem, exploring possible explanations, identifying knowledge gaps, researching and experimenting to fill those gaps, applying the findings to the problem, and reflecting on what was learned along the way. The theoretical underpinnings for this approach harmonize well with

the constructivist view that students gradually piece together information that is altering or reinforcing their mental explanatory models (Schmidt, et al., 2017). Students, however, may benefit from the guidance offered by a systematic approach; a framework that can help lead them to efficient use of their energies and potentially better outcomes. Herreid (2004) recognized this deficiency: “I do believe there are better ways to solve problems—by developing habits of mind that speed things along” (p. 12). Herreid (2004) went on to argue that the best way to instill a problem-solving framework is to model it in a discipline appropriate way. Therefore, instructors should contemplate modelling problem-solving habits to their students and incorporate methodologies that are conducive to presenting real-world problems that need solved.

Finally, teachers facing mounting pressure to cover mushrooming curriculum may discover that the directed case study method offers a viable alternative to lectures in several ways. First, the method is adaptable to content-heavy classes (Pai, 2009; Woody et al., 1999). Second, the method cultivates student interest and engagement through the relevance of storytelling (Centin-Dindar, 2016; Wolter, Lundeberg, & Bergland, 2013). Third, the method requires that students apply the content to a real-world situation to some degree (Cliff & Wright, 1996; Schmidt, 2009). Through this dissertation, the author has contributed to the sparse quantitative research on the effects of the directed case study method on high school students’ critical thinking skills. In addition, the author has outlined an example of repeated measures study design in an education setting and highlighted the attributes of the directed case study method.

Recommendations for Further Research

This study was designed to investigate empirically the influence of the directed case study method on the critical thinking skills of high school students. Pursuing the answer to this

question raises many more questions in the process. For instance, repeating the experiment at various times during the school year, or perhaps extending the study to an entire quarter or semester. This study only used two case studies over the course of six weeks. It would be interesting to discover how many iterations of directed case studies must occur before there is a statistically significant effect and if that effect continues to grow over time. Furthermore, it would be informative to explore the degree of implementation necessary to garner significant results.

Few studies on CBT have been conducted at the high school level, although it is a growing hotspot for CBT. In a survey of 1,634 teachers who used case studies in their lessons, 588 taught at the high school level (Herreid, Schiller, Herreid, & Wright, 2011). This study was designed to build on the scant research on CBT at the secondary level by incorporating multiple teachers in the study, where most researchers to date have compared two teachers at most (Antepohl & Herzig, 1999; Chaplin, 2009; Flynn & Klein, 2001; Grunwald & Hartman, 2010; Kulak, Newton & Sharma, 2017; Noblitt, Vance & Smith, 2010; Pai, et al., 2010; Preszler, 2014). Further studies that included matching multiple teachers in both the control and experimental groups would strengthen the findings of this study. Creation of an effective and inexpensive critical thinking measure would facilitate further research into the effectiveness of CBT. Educators could use the instrument to probe specific characteristics of critical thinking such as reasoning, analysis, and application as well as test the integration of those skills with a series of problems. The research could be two-fold. First, the creation of such an instrument would be practical to future research efforts. Second, the test could help investigators examine the holistic nature of critical thinking (Lai, 2011). A validated instrument of this nature could be

used to test several instructional methods simultaneously to discover which methods are most effective for improving critical thinking.

The directed case study method is one of many ways to implement CBT. Follow up research comparing the other methods of CBT to critical thinking, content knowledge, and student enjoyment could be a profitable endeavor. Klegeris and Hurren (2011) suggested, “The superiority, or at least the noninferiority, of PBL over standard course delivery techniques must be proven for each individual PBL delivery method” (p. 409). Just as each method of PBL needs to be tested, each method of CBT needs to be researched for strengths and weaknesses. In a similar vein, the aspects of CBT could be explored to discover the relative importance of the storytelling as opposed to the systematic problem-solving. CBT could also be compared to other instructional frameworks such as Inquiry Based Learning or Flipped Classrooms, to examine the strengths and weaknesses of different methodologies. Rather than a comparison via meta-analysis, the comparison could be deliberate and empirical.

Conclusion

Teachers regularly face the difficult task of selecting an appropriate methodology to meet their instructional goals. The decision must be weighed against the demands of student interest, available resources, curriculum obligations, educational philosophy, standardized testing and career readiness. The goals may be as varied as reading comprehension or critical thinking. Most educators concur that critical thinking skills are an important outcome of the educational process. Nevertheless, achieving the goal of improving the critical thinking skills of students remains elusive. This research study focused on the directed case study method as a mechanism to improve the critical thinking skills of high school students. The results could not unequivocally demonstrate that the directed case study method will improve critical thinking test scores, but the

findings do have some merits. The findings suggest that the directed case study method may hold student interest, and is a feasible option for teachers seeking intermediate, active learning alternatives to direct instruction. The feasibility is augmented by the relative ease with which the directed case study method can be adopted to content heavy classes.

The importance of promoting critical thinking to modern education cannot be overstated. Discovering the best practices that encourage students to learn to think critically should be at the forefront of educational research. The unique repeated measures design of this dissertation provides a template for future inquiry into measuring the effectiveness of teaching pedagogies. Empirical, quantitative research is needed to buttress the claims of the qualitative literature regarding CBT and critical thinking. The case for case studies still hangs in the balance, and much empirical research remains to be done before a final verdict can be reached.

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Appendix A: Student Assent Form

Dear Student,

My name is Mr. Dan Weaver, and I am a student at Concordia University. I am doing a project to learn if case studies help you to develop critical thinking skills. I am asking you to be involved in a research project.

You will be asked to take three critical thinking tests. Once at the start of the study, once in the middle and once at the end of the study. Each test consists of 20-questions. The testing sessions last about 25 mins.

You may find that it is fun to know more about your critical thinking skills. Some people pay lots of money to take critical thinking tests for employers and college applications. I hope to find out more about helping students improve their critical thinking.

The critical thinking tests will not be used as a grade in your biology class.

Immediately after each test, you will be able to view your individual scores, but you do not need to tell anyone what score you received. Only the average scores will be used in the study. No one will know your personal scores or your personal information.

Your teacher will either use a case study to teach a unit or will not use a case study to teach a unit. Everyone in the classroom will be taught the same way, whether they participate in the study or not.

Students who return their parental permission slips and this form will be entered into a drawing for one of three 10\$ gift cards.

You do not have to be in this study. If you decide to be in the study, you can stop at any time. You do not have to take all of the tests.

If you have any questions, you can ask me at any time. You can also write or call the director of the board that oversees this type of research: Dr. OraLee Branch (email obranche@cu-portland.edu or call 502-493-6390

Please put a check next to one sentence. Then sign the form.

I **want** to be in the study _____

I **do not want** to be in the study _____

Name: _____

Signature: _____

Date _____

Appendix B: Teacher Participant Research Consent Form

Title of Project: The Case for Case Studies

Principal Investigator: Dan Weaver

Study Background:

This study proposes to compare the effect of the directed case study method to traditional, didactic methods on the growth of critical thinking skills. The results are significant for at least two reasons. First, the research may establish a link between the directed case study method and critical thinking growth, making Case-based Teaching a viable option for teachers looking for a methodology that develops critical thinking. Teachers would be interested in teaching methods that not only provide content information, but also prepare students for the future. Second, no single teaching method can achieve all educational goals, however, empirically knowing what goals a methodology can and cannot achieve is valuable information to any educator.

Procedures:

The first step will be announcing to your classes that you are part of a research study. The study is quasi-experimental, but it gives the students an opportunity to experience the scientific method in action. Everyone in the class will be taught the same way.

The next step is distributing and collecting permission slips. Both parental permission and student assent is required to participate in the study. Students who turn in both permission and assent form will be eligible to win one of three 10\$ gift cards.

The third step requires establishing baseline data. Students will take a 20-question critical thinking exam. You will proctor the 25 minute exam. Students will log into Google classroom

and enter a code to have access to the test. Only test averages will be used, not individual student data. You may offer extra credit to test-takers, if you offer an alternate to non-testers

The fourth step is to find two directed case studies from the Nation Center for Case Study Teaching in Science. The case studies should correspond to the current topic of instruction. Teaching notes, tips, and answer keys will be provided to you.

Fifth, prepare to incorporate one case study into your lessons over the course of a three week time period. Feel free to assign homework, quizzes, and other activities related to the content or case study. A second critical thinking test will be administered at the end of the three week period.

Sixth, use the second case study as a framework to teach over the course of three more weeks. The final critical thinking assessment will be administered at the end of the three week period.

Benefits

The project will provide both you and the students with firsthand exposure to a research study in education. The experience may encourage you to consider using CBT in the future. With the rise in popularity of such tests, students may feel more confident about taking a critical thinking assessment in their future.

Alternatives

You are free to quit/stop at any time in this study

Confidentiality

All data from this study will be kept as private as possible. Permission and assent forms will be locked. Electronic data will be stored on a password protect laptop on a password

protected website. Immediately after the testing individual student data will be disassociated from their scores.

Contacts

Dan Weaver

Dr. OraLee Branch

IRB Director

obranch@cu-portland.edu

503-493-6390

Please complete this form:

_____ I want to participate in this study

_____ I DO NOT want to participate in this study

Print Name: _____

Signature: _____ Date _____

Appendix C: Parental Consent

CONSENT FORM

Research Study Title: Case for Case Studies

Principal Investigator: Dan Weaver

Research Institution:

Faculty Advisor: Dr. Belle Booker

Purpose and what you will be doing:

The purpose of this study is to compare how two teaching methods effect critical thinking. We expect to use general biology students in the 9th and 10th grades. No one will be paid for the study, but students who return their permission slips will be entered into a drawing to win a gift card. The study will last approximately six weeks. The participants will take three 20-question critical thinking tests.

Risks:

There are no risks to participating in this study other than accessibility to the critical thinking test scores. However, we will protect your information. Any personal information, like your name, ethnicity or test scores, will be coded so it cannot be linked to you. Any demographic or identifying information you give will be kept securely in locked storage. When we or any of our investigators look at the data, none of the data will have your name or identifying information. We will use randomly assigned numbers to identify the tests. We will not identify you in any publication or report. Your information will be kept private at all times, and then all permission forms, and other demographic information will be destroyed after a period of three years.

Benefits:

Your participation will help us see how well a teaching method works to improve critical thinking skills.

Your participation will also help other research project that may have a similar design.

Confidentiality:

This information will not be distributed to any other agency and will be kept private and confidential. The only exception to this is if you tell us of abuse or neglect that makes us seriously concerned for your immediate health and safety.

Right to Withdraw:

Your participation is greatly appreciated, but we acknowledge that taking the tests are voluntary. You are free at any point to choose not to engage with or stop the study. This study is not required and there is no penalty for not participating. If at any time you would wish to stop participating you may.

Contact Information:

You may request a copy of this consent form. If you have questions you can talk to or write the principal investigator,
Dan Weaver
Email:

If you want to talk with a participant advocate other than the investigator, you can write or call the director of our institutional review board, Dr. OraLee Branch (email obranche@cu-portland.edu or call 503-493-6390).

Your Statement of Consent:

I have read the above information. I asked questions if I had them, and my questions were answered. I volunteer consent for my child, if my child wishes to participate in this study.

Participant Name

Date

Parent Signature

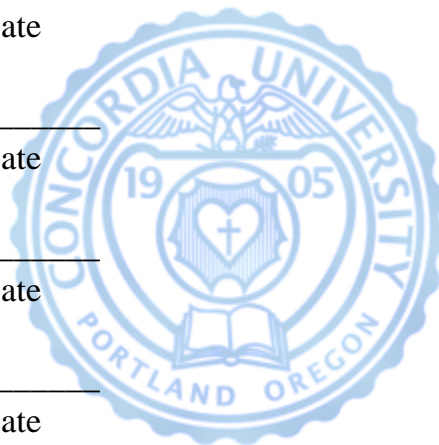
Date

Investigator Name

Date

Investigator Signature

Date



Investigator: Dan Weaver email:
c/o: Professor Dr. Belle Booker
Concordia University – Portland
2811 NE Holman Street
Portland, Oregon 97221

Appendix D: Proctor Instructions

Paper version- Prior to the Testing Session

1. Ensure that every test taker has a pencil
2. Ensure that you have enough copies of the CT test.
3. Absent students can take the test up to two days later.
4. Prepare an alternative assignment for the non-test takers- I suggest a word find or crossword with biology terms. Both the CT test and the crossword can be counted for extra credit points (I recommend 5 points each)

Beginning Your Testing Session

1. Instruct the test-takers NOT to write their names on the scantron.
2. Instead students should write the randomly assigned number in the space for their name.
3. Students write the randomly assigned number on the top right hand corner of the test

Inform the test-takers

1. You do not have to take this test. You will not be penalized if you do not take this test.
2. Questions should be answered in order. Once a question is answered you can go back and change it.
3. You will have up to 25 minutes to complete the test.
4. Read the directions carefully!

Start the testing session

1. Distribute the testing materials
2. Students may begin when ready
3. Start the stop watch
4. No additional study helps are allowed
5. Do not clarify or comment on any question
6. Maintain a distraction free environment

Ending the testing session

1. All tests must be turned in at the end of the 25 minute time limit.
2. Any tests that are returned in 8mins or less need to be marked with an "X" above the ID number
3. Any tests that are incomplete after 25 mins need to be marked with an "XX" above the ID number
4. Students need to remain quiet while other test-takers are still working
5. Place the tests and scantrons together in the envelope. Place the envelope in DAN WEAVER'S mailbox.

Proctor Instructions (continued)

Computer version- Prior to the Testing Session

5. Ensure that every test taker has access to a computer
6. Make sure that the computers are charged and working correctly
7. Prepare an alternative assignment for the non-test takers

Beginning Your Testing Session

4. Instruct the test-takers to login to their school accounts
5. Navigate to google.com and select google classroom.
6. Direct the students to the provided classroom code. The classroom code will grant students access to the tests and register the students.

Inform the test-takers

5. You do not have to take this test. You will not be penalized if you do not take this test.
6. Questions should be answered in order. Once a question is answered you can go back and change it.
7. You will have up to 25 minutes to complete the test.
8. Immediately after the test you will be able to see your results. Do not share this information with anyone.

Start the testing session

7. Make sure all students are logged in and on the correct page
8. Students may begin when ready
9. No additional study helps are allowed
10. Do not clarify or comment on any question
11. Maintain a distraction free environment

Ending the testing session

6. Students may log off once the test is completed
7. Students need to remain quiet while other test-takers are still working

Appendix E: Study Script

Study Introduction Script:

Teachers use a variety of teaching methods. You may have experienced some cooperative learning activities, some inquiry based lab activities, and some note taking activities. Teachers use different strategies like these to accomplish different goals. But who decided how well teaching strategies work? Researchers develop teaching strategies and then do an experiment to determine how well the new idea works.

You are probably familiar with the scientific method and how to do experiments. In an experiment you have a control group and an experimental group. The experimental group is treated slightly differently to see if there is any effect. This is an opportunity to be part of a real live experiment. The results of this experiment may be a great help to students and teachers in the future.

Your teacher will teach everyone in the same way over the course of the next 6 weeks. Those of you who are participating in the study will take three tests. The tests will be used to determine the benefits of the teaching method. Those who are not taking the tests will do an alternative assignment.

The tests are meant to measure your critical thinking skills. Many people pay lots of money to take critical thinking tests. Colleges and employers often require people to take critical thinking tests. You will be able to take these tests for free.

Taking the tests will not have a negative impact on your biology grade. Your performance will not be recorded in Sapphire. Your name will not be on the test, only a random number. No researcher will be able to tell who took the test.

To be part of this exciting experiment you will need a permission slip from your parents. You will also need to sign a form. The forms will be stored in a secure and locked location. Those of you who return both forms will be entered into a drawing to get one of three \$10 iTunes gift cards.

You will be allowed to drop out of the study at any time. You do not have to take the tests if you do not want to.

I hope that you will decide to participate! Bring your permission slips in by tomorrow.

Appendix F: Statement of Original Work

The Concordia University Doctorate of Education Program is a collaborative community of scholar-practitioners, who seek to transform society by pursuing ethically-informed, rigorously-researched, inquiry-based projects that benefit professional, institutional, and local educational contexts. Each member of the community affirms throughout their program of study, adherence to the principles and standards outlined in the Concordia University Academic Integrity Policy. This policy states the following:

Statement of academic integrity.

As a member of the Concordia University community, I will neither engage in fraudulent or unauthorized behaviors in the presentation and completion of my work, nor will I provide unauthorized assistance to others.

Explanations:

What does “fraudulent” mean?

“Fraudulent” work is any material submitted for evaluation that is falsely or improperly presented as one’s own. This includes, but is not limited to texts, graphics and other multi-media files appropriated from any source, including another individual, that are intentionally presented as all or part of a candidate’s final work without full and complete documentation.

What is “unauthorized” assistance?

“Unauthorized assistance” refers to any support candidates solicit in the completion of their work, that has not been either explicitly specified as appropriate by the instructor, or any assistance that is understood in the class context as inappropriate. This can include, but is not limited to:

- Use of unauthorized notes or another’s work during an online test
- Use of unauthorized notes or personal assistance in an online exam setting
- Inappropriate collaboration in preparation and/or completion of a project
- Unauthorized solicitation of professional resources for the completion of the work.

Statement of Original Work (continued)

I attest that:

1. I have read, understood, and complied with all aspects of the Concordia University-Portland Academic Integrity Policy during the development and writing of this dissertation.
2. Where information and/or materials from outside sources has been used in the production of this dissertation, all information and/or materials from outside sources has been properly referenced and all permissions required for use of the information and/or materials have been obtained, in accordance with research standards outlined in the *Publication Manual of The American Psychological Association*



Digital Signature

Daniel J Weaver

Name (Typed)

10/02/2018

Date