AN INVESTIGATION OF THE RELATIONSHIP BETWEEN STUDENT CRITICAL THINKING SKILLS AND PROFESSIONAL DEVELOPMENT

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Jennifer McAdam

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Major Professor: Lynn, Bohecker, Ph.D.

AUTHORIZATION TO SUBMIT

DISSERTATION

This dissertation of Jennifer McAdam submitted for the degree of Doctor of Philosophy with a major in Educational Leadership and titled "An Investigation of The Relationship Between Student Critical Thinking Skills and Professional Development" has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies.

Major Professor DocuSigned by: Lynn Bohecker C2F83F2F1F6F42A... Dr. Lynn Bohecker Date 5/13/2020 | 22:41:48 MDT

Committee Members DocuSigned by: Christa Sandidge 938B8871131744F... Dr. Christa Sandidge Date 5/14/2020 | 07:02:15 PDT

DocuSigned by: Dan Everett B2938F452C44483... Dr. Dan Everett Date 5/16/2020 | 12:14:59 PDT

Program Director DocuSigned by: Heidi Curtis 18C507285A124B4... Dr. Heidi Curtis Date 5/18/2020 | 10:13:14 MDT

Discipline's College Dean DocuSigned by: Lori Sanchez 1F6287564ACC4DC... Dr. LoriAnn Sanchez Date 5/18/2020 | 10:16:37 MDT

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DEDICATION

This study is dedicated to my loving husband and children who allowed me countless hours of peace and quiet to write on evenings and weekends. I also dedicate this to my mom, my biggest cheerleader. Thank you, mom, for always believing in me. Your heart is gold. Thank you for all your love and support. Lastly, this study is dedicated to my dad, who gifted me with determination and perseverance; I wish you were here to see me graduate!

ABSTRACT

A quantitative between-group design included two treatment groups and a control group to explore if teacher participation in critical thinking professional development impacted critical thinking skills in high school students. Treatment group TG1 included students from three class sections, and the teachers in this group enrolled in a structured asynchronous online professional development course with a weekly design. Treatment group TG2 consisted of students from three class sections, and the teachers enrolled in an asynchronous professional development with a modular design with no facilitator oversight. Both professional development treatments consisted of the same information. The control group CG1 included students from four class sections. The teachers of the control group students did not participate in any critical thinking professional development during the semester. Based on results from dependent *t* tests, a statistically significant increase was seen in advanced level high school student's overall critical thinking skills, as well as analysis, inference, evaluation, induction, and deduction subsets, in both treatment group TG1, whose teacher was enrolled in PD1, a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking, and treatment group TG2, whose teacher was enrolled in PD2, a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates. Using ANCOVA to analyze the differences between groups, statistically significant differences between the posttest mean of treatment group TG1 and treatment group TG2 were found in both overall critical thinking skills, and the inductive subset. Differences between treatment group TG1 and the control group CG1 were found in overall critical thinking, and analysis, inference, and induction subsets. There were no statistical differences between posttest means of treatment group TG2 and the control group CG1. This

study could help provide direction for professional development in a subject that is currently underprovided in professional development.

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Chapter I

There is a lack of critical thinking skills in students graduating from high school and college (Fadhlullah & Ahmad, 2017; Forbes, 2018; Glaser, 1984; National Education Goals Panel, 1992; Schneider & Miller, R, 2005; ten Dam & Volman, 2004). Critical thinking is an essential life skill in a successful, high functioning society (Heinrich et al., 2015; Koenig, 2011; Nirmala & Kumar, 2018; Paul, Elder & Bartell, 1997; ten Dam, & Volman, 2004; Williams, 2005; Wulandari et al., 2017). Critical thinking skills are essential to learning as they are applied when analyzing social, ethical, environmental, and moral issues (Samanci, 2015). Critical thinking is a crucial aspect as competent citizens need critical thinking skills to participate in democratic culture fully, and those skills enable them to be contributing members of society (Husamah et al., 2018; Nirmala & Kumar, 2018; ten Dam, & Volman, 2004). There is a statistically significant positive relationship between moral judgment and critical thinking skills (Samanci, 2015). A study by Butler (2012) found that individuals with higher critical thinking skills reported less adverse life events when compared with individuals with lesser critical thinking skills. Critical thinking is uniquely well suited for messy, ill-defined, complex problems, which is why it is so crucial for students to learn in order to fully function in a democratic society (ten Dam & Volman, 2004).

Given the number of children that attend school, teachers, principals, and districts have the opportunity to resolve the lack of critical thinking of graduating students. This study aims to examine the phenomenon of teacher participation in critical thinking professional development and the effect on students' critical thinking skills. The professional development in this study was specifically designed to prepare teachers to infuse critical thinking into their instruction. To improve critical thinking skills in today’s students, teachers need to be trained with the goal of

increasing students' critical thinking levels. Teachers need to develop critical thinking skills in order to disseminate the information to their students efficiently (Ennis, 1985; Samanci, 2015; Zhou et al., 2012). Although many teachers aspire to teach higher order thinking skills, they often either lack the knowledge to do so or lack the techniques to teach these higher-order skills. (As' ari et al., 2017; Cansoy &Türkoglu, 2017; Geçit & Akarsu, 2017; Whittington, 1995). To achieve critical thinking on a societal level, these skills need to be widely taught in schools in order for students to become critical thinkers (Alexander, 2014).

Teachers have the duty to teach students the critical thinking skills that support social, ethical, environmental, and moral decision making processes (Samanci, 2015). Teachers help mold and model democratic individuals that have developed different ways of thinking, and to do so, the teachers themselves must possess these same critical thinking skills (Paul et al., 1997; Samanci, 2015). To successfully teach critical thinking skills, the language and practice of using critical thinking skills need to be practiced on a daily basis (Sherblom, 2010). Spending too much time memorizing facts and not conceptualizing them inhibits students' development of critical thinking skills (Sherblom, 2010). Whittington (1995) found that educators teach at lower levels of cognition 98% of the time. In order for teachers to teach at a higher level of cognition, they need to be trained on how to do so. This study examines how various professional development aimed at not only increasing teachers' critical thinking skills but also training teachers on how to infuse critical thinking skills into their instruction, may be able to rectify the lack of critical thinking in education.

Students are not born with the ability to think critically; if instructors want to teach critical thinking to their students effectively, they need to be able to model critical thinking in their classrooms (Ennis, 1985; Facione, 1990; Hemming, 2000; Wulandari et al., 2017).

Educators need to possess the ability to use and apply critical thinking skills, so their students can acquire and develop these essential skills that are required in today's society (Cotter & Tally, 2009). To successfully teach critical thinking skills, teachers and faculty must also model the behaviors and practice critical thinking themselves (Facione 1990; Sherblom, 2010).

When people are presented with enormous amounts of information, which is common in the internet age, if they have not developed a specific way to wade through the false versus true material, they are unable to come to a legitimate factual conclusion (Halpern, 1998). Halpern (1998) writes:

> If people cannot think intelligently about the myriad issues that confront them, then they are in danger of having all of the answers but still not knowing what the answers mean. The dual abilities of knowing how to learn and knowing how to think clearly about the rapidly proliferating information that they will be required to deal with will provide the best education for citizens of the 21st century. (p. 450)

Often students are taught to take what their teacher says as fact and not question or challenge information or apply critical thinking to the information, but one of the essential aspects of critical thinking is to question the information given and learn how to find the valid authority on the problem or question at hand (Combs et al., 2009; Paul, 2005; Paul et al., 1997; Sigel, 1984; Wang, 2017). An inherent aspect of critical thinking is the questioning of power in social constructs and relations (ten Dam & Volman, 2004). To become a participant in society, curriculum needs to be designed in a way that contributes "to the ability as well as the readiness of students to participate independently in a meaningful and critical way in concrete real social practices and activities" (ten Dam & Volman, 2004, p. 371). Only learning a set of skills or

applying tricks to arguing is not enough to develop the essential critical thinking skills to be a contributing member of society.

Although much research has been done on how to teach students best how to think critically, research has not thoroughly looked at the role that the teachers' critical thinking skills play on the students' development of critical thinking. One way to possibly make a significant change in the critical thinking skills in as many students as possible is a tool that can reach a wide-ranging audience in a relatively short amount of time. This study aims to look at how professional development on how to infuse critical thinking into instruction affects students' critical thinking levels.

Statement of the Problem

Critical thinking is a backbone of democracy (Paul et al., 1997), and considering the numbers of students educated in the democracy of the United States, Williams (2005) stated that teachers could affect the critical thinking skills of an entire generation. Critical thinking is an essential educational goal (Facione, 1990; Gashan, 2015; Glaser, 1984; Murphy et al., 2014; Seymour & Levin, 2015). Critical thinking is important because it allows individuals to make effective decisions and solve problems that are essential in the workplace (Snyder & Snyder, 2008). Critical thinking is essential in society; adults often fail to recognize all the information in a situation, which can lead them to flawed conclusions (Norris, 1985). Without critical thinking, the quality of reasoning can be degraded on a societal level, which can lead to a breakdown between critical thought and action, a link that critical thinking instruction is designed to accomplish (Norris, 1985).

Students who can think critically have the ability to solve real-world problems (Snyder & Snyder, 2008). Recent research has established that higher critical thinking skills are associated

with job performance and more favorable real-world outcomes (Butler, 2012). Employability is a universal problem (Nirmala & Kumar, 2018). Employability is a combination of skills, knowledge, ability, competency, and capability that help an individual get, make a productive contribution to, and advance in a job (Nirmala & Kumar, 2018). Cotton (2000) summarized the three main types of skills most needed for employability, including basic skills, higher order thinking skills, and effective skills. Soft skills such as critical thinking have become very important to employers as they believe they can train technical skills to employees, but soft skills are more challenging to teach in the workplace (Nirmala & Kumar, 2018). Higher order thinking skills, including critical thinking, have a significant impact on employability skills and, therefore, need to be possessed by students entering the workforce (Nirmala & Kumar, 2018).

There is a lack of critical thinking skills in students graduating from high school and college (Glaser, 1984; Nirmala & Kumar, 2018; National Education Goals Panel, 1992; ten Dam & Volman, 2004). Much traditional curriculum does not take into account or reflect the critical thinking skills needed by students (Geçit & Akarsu, 2017; Moore & Stanley, 2010). In 1983 the publication *A Nation at Risk* reported that 40% of students lacked critical thinking skills needed to make inferences from written material, and by 1990 most states promoted critical thinking to educators (Willingham, 2008); even so, critical thinking skills in students remain deficient in the primary, secondary and the post-secondary levels (Evens et al., 2013, 2014; Forawi, 2016; Innabi & Sheikh, 2007). Even after years of research and implementation of many programs and development of new curriculum designed to increase critical thinking skills, students today still have a deficiency in critical thinking skills (Nirmala & Kumar, 2018; Willingham, 2008).

There is an insufficient level of critical thinking in educators (Moore & Stanley, 2010; Turan, 2016; Zhou et al., 2012). Although educators agree that critical thinking skills are

essential, many educators are not cognizant that they lack the concept of critical thinking, and some erroneously believe they are teaching critical thinking skills (Bedosky, 2013; Gashan, 2015; Geçit & Akarsu, 2017; Marin & de la Pava, 2017; Paul, 2005; Rieck, 2013; Stedman & Adams, 2012). If teachers are not educated on how to develop critical thinking skills themselves, they are unable to teach their students how to develop these skills (Ennis, 1985; Gashan, 2015; Moore & Stanley, 2010; Williams, 2005; Yoon et al., 2007). While studies have established that critical thinking is essential for students to master, if teachers are not trained to disseminate information about critical thinking to their students effectively, students will not obtain the needed skills (Ennis, 1985; Samanci, 2015; Zhou et al., 2012).

To enact long-term change and success, teachers and faculty members need to develop a fundamental understanding of what critical thinking is and develop the skills to efficiently disseminate the practice of critical thinking to their students in a way that students can apply them (Bedosky, 2013; Paul, 2005; Tiwari et al., 2006). To successfully teach and integrate these skills into their instruction, educators need to be clear on the definition of critical thinking and master the skills on how to effectively teach it (Moore & Stanley, 2010; Paul, 2005; Whitworth & Chiu, 2015). When Bedosky (2013) studied current professional development in the area of critical thinking, the study found that teachers do not feel prepared to teach critical thinking skills based on the professional development in which they currently participate.

Even when teachers are educated with the focus of increasing student critical thinking skills, often the results show little if any statistically significant improvement in the students' critical thinking skills (Agdas, 2013; Gunn et al., 2008; Innabi and Sheikh, 2007; McGuire, 2010; Phelan, 2012; Rohrer, 2014). Many studies had professional development interventions that are shorter in duration, lacked content specificity, intensity, and focus than recommended for

effective professional development, and these could possibly be reasons why these studies showed little to no increase in student critical thinking skills. Professional development should be widely accessible, flexible, include a minimum of twenty hours, be content focused, high quality, well planned, integrate active learning activities, employ scientifically proven curriculum models, provide expert support and coaching, and include reflection and feedback (Banilower et al., 2007; Carey et al., 2008; Darling-Hammond et al., 2017; Dash et al., 2012; Desimone, 2011; Gerard et al., 2011; Shaha & Ellsworth, 2013; Yoon et al., 2007).

For there to be effective critical thinking, course content, activities, and teaching procedures need to be focused on how they will increase students' critical thinking skills (Nosich, 2005). Successfully designed professional development can change teachers' perceptions, their teaching practices, and increase student outcomes (Meiers & Ingvarson, 2005). Professional development programs can impact the professional learning of the teachers involved by changing the way they approach teaching and the way they design their units (Meiers & Ingvarson, 2005).

There is an absence in the literature regarding the outcomes of high quality, long term, and critical thinking content focused professional development and its ability to effectively train teachers to infuse essential critical thinking skills into their instruction effectively. The purpose of this study is to explore if professional development has the ability to impact students' critical thinking skills.

Background

Critical thinking has been studied widely in the past twenty years with many different definitions developed to describe it (Combs et al., 2009; Glaser, 1984; Lennon, 2014; Šarić & Šteh, 2017; Paul, 1992; Wang, 2017). While researchers and educators agree that students need

to have sufficient critical thinking skills to be successful in school, there is no one agreed definition or way critical thinking skills should be taught to students (Glaser, 1984; Ku, 2009; Murphy et al., 2014, Schneider & Miller, 2005). Although there is varied disagreement on a universal definition of critical thinking, the importance of critical thinking has a mostly universal agreement (Al-degether, 2009; Ganapathy et al., 2017; Glaser, 1984; Ku, 2009; Murphy et al., 2014, Schneider & Miller, 2005; Scriven & Paul, 2004; Wang & Zheng, 2016; Wulandari et al., 2017). For the purpose of this study, the definition of critical thinking used was adapted from Facione (1990) in the APA Delphi study, where various experts in the field agreed on an overall definition of critical thinking. Critical thinking is purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based (Facione, 1990).

Studies have shown that teachers can help students increase their critical thinking skills and increase student achievement (Murphy et al., 2014; Parrott & Rubinstein, 2015; Rahmati et al., 2018; Schindler & Burkholder, 2014; Shaha & Ellsworth, 2013; Tsui, 2002; Wulandari et al., 2017). Over the years, educators have used many different techniques to incorporate critical thinking skills in order for students to develop and practice these skills. Some of the ways critical thinking can be taught include explicit, discussion-based, embedded, inquiry-based, and problem-based learning (Ganapathy et al., 2017; Linthacum, 2011; Marin & Halpern, 2011; Silm et al., 2017; Tsui, 1999). In order for teachers to employ and incorporate critical thinking into their instruction, the teachers need to first learn the skills themselves in order to model and teach these essential skills to students.

Professional development is not widely available in the area of critical thinking, and

teachers do not feel like they have the proper training to teach critical thinking skills effectively (Bedosky, 2013; Lennon, 2014; Marin & de la Pava, 2017). The professional development in this study, including online professional development, allows educators to have more accessibility and flexibility in choosing when and what they are learning, which has been shown to produce a favorable outcome when compared with traditional in-service professional development (Carey et al., 2008; Dash et al., 2012; Shaha & Ellsworth, 2013). The purpose of this study is to determine if professional development impacts students' critical thinking levels.

Research Questions

Research questions narrow the focus and help to clarify the general and specific directions of a study (Creswell, 2015). A quantitative pretest-posttest research design was chosen to explore the research questions in this study. The focus of this study is if and how teacher participation in professional development impacts student critical thinking skills; therefore, the following research questions will be addressed:

RQ1: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact critical thinking skills of high school students taking college preparatory classes as measured by the overall score on the California Critical Thinking Skills Test?

RQ2: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact analytical reasoning skills of high school students taking college preparatory classes as measured by the analysis subset score on the California Critical Thinking Skills Test?

RQ3: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact inference skills of high school students as measured by the inference subset score on the California Critical Thinking Skills Test?

RQ4: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact evaluative reasoning skills of high school students as measured by the evaluation subset score on the California Critical Thinking Skills Test?

RQ5: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact decision-making skills of high school students as measured by the induction and deduction subset scores on the California Critical Thinking Skills Test?

Description of Terms

The following terms are specifically associated with professional development, critical thinking texts, and studies. Describing terms is essential as it helps enhance consistency and understanding (Creswell, 2015).

Critical thinking skills. Purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based (Facione, 1990).

Critical thinking disposition. The predisposed attitude that students naturally possess with regards to using critical thinking skills. Critical thinking disposition is the ability to use critical thinking when needed (Facione, 1990).

Dual Process Thinking. The assumption by many theorists that cognitive tasks evoke two forms of processing that contribute to observed behavior. (Evans & Stanovich, 2013)

Higher-order thinking skills (HOTs). Bloom categorized thinking skills, beginning from the concrete and progressing to the abstract: knowledge, comprehension, application, analysis,

synthesis, and evaluation (Bloom, 1956). The last three levels of Bloom's Taxonomy, analysis, synthesis, and evaluation are considered higher-order thinking skills (Johnson & Lamb, 2011).

Inquiry-based learning. Consists of students developing their own questions, gathering data, diagnosing problems, and interpreting their results (Colburn, 2000).

Online professional development. Online learning intended to help administrators, teachers, and other educators improve their professional knowledge, competence, skill, and effectiveness.

Pedagogical content knowledge. Pedagogical content knowledge is the integration of subject expertise and skilled teaching of that particular subject.

Pedagogy. The method and practice of teaching, primarily as an academic subject or theoretical concept.

Professional development. Learning intended to help administrators, teachers, and other educators improve their professional knowledge, competence, skill, and effectiveness.

California Critical Thinking Skills Test. A comprehensive and foundational critical thinking concepts and principles test (Foundation for Critical Thinking, 2017).

Analysis. Includes analytical reason skills that enable how people identify assumptions and claims and how they interact to form an argument (Insight Assessment, 2019).

Interpretation. Interpretation includes identifying, categorizing, decoding significance, clarifying meaning and paraphrasing arguments (Facione, 1990; Wang, 2017)

Inference. Inference skills enable students to draw conclusions from evidence or facts.

Evaluation. Consists of evaluative reasoning skills which are used to assess the credibility of claims and presented information while determining the strength of arguments (Insight Assessment, 2019).

Explanation. Includes explanatory reasoning skills accessed before making a final decision (Insight Assessment, 2019).

Induction. Consists of decision-making skills based on drawing inferences about what an individual thinks is true based on data, patterns, experiences, and behaviors (Insight Assessment, 2019).

Deduction. Related to induction, yet it includes decision-making skills that are based on rules, values, policies procedure and are logical and clear cut (Insight Assessment, 2019).

Significance of the Study

This study explores if teacher participation in critical thinking professional development can affect the growth of critical thinking skills in students. Teachers strive to develop and implement a pedagogy that can increase the higher order thinking skills but lack the training to do so (As'ari et al., 2017; Cansoy & Türkoglu, 2017; Geçit & Akarsu, 2017; Whittington, 1995). Many teachers agree that teaching critical thinking skills is essential, yet professional development in the area of critical thinking is deficient and not readily accessible, which creates disjointed instruction (Bedosky, 2013; Nicholas & Raider-Roth, 2016).

Typical professional development is short in its duration, and often the teacher leaves with no concrete way to integrate the knowledge into the classroom (Banilower et al., 2007; Gerard et al., 2011). Using a flexible format to teach critical thinking skills, while giving teachers a concrete way to integrate those skills into their classrooms, could have a far-reaching effect from elementary to university levels. This study found that teachers are able to integrate the information they have learned into their classrooms to a point where a measurable difference in critical thinking skills is found in their students.Therefore critical thinking professional development has the potential to help transform the educational system. This study could help

provide direction for high-quality professional development in a subject that is currently underprovided in professional development (Bedosky, 2013; Smith et al., 2003; Van der Werff, 2016).

Overview of Research Methods

The study will use quantitative data applied to study the impact of professional development on student critical thinking skills in the form of pretesting and post-testing using the California Critical Thinking Skills Test for student participants. The California Critical Thinking Skills Test focuses on the eight subsets of critical thinking (a) overall (b) analysis (c) interpretation (d) inference (e) evaluation (f) explanation (g) induction (h) deduction (Insight Assessment, 2019). Mertler (2016) states that quantitative studies seek to establish relationships between variables, and the process is well established. A quantitative between-group design using a control group, and three intervention groups was selected for the research design. Experimental research designs include two or more groups, an independent variable that can be manipulated as well as a dependent variable that can be measured in all groups (Creswell, 2015).

The population for this study was upper-level students enrolled in three high schools in the western United States. Convenience sampling was used to select the participants in this study. Individuals were identified from previously formed college preparatory, honors or Advanced Placement junior- and senior-level classes. The student participants were 49% female and 50% male, and 1% declined to state, with an average age of 17 years old. There were three groups: treatment group TG1, treatment group TG2, and the control group CG1. Teachers were a part of the interventions; teachers from treatment group TG1 and treatment group TG2 participated in two different semester long professional development programs developed to teach educators how to infuse critical thinking skills in their instruction. Student participants in both the control

and intervention groups took the California Critical Thinking Skills Test at the beginning and end of the semester. Statistics, including *t* tests, and ANCOVAs, in addition to descriptive statistics using SPSS software, were performed at the conclusion of the study.

Chapter II

Review of Literature

Introduction

Critical thinking is an imperative skill (Heinrich et al., 2015; Koenig, 2011; Nirmala & Kumar, 2018; Paul et al., 1997; ten Dam & Volman, 2004; Williams, 2005; Wulandari et al., 2017). Critical thinking was first proposed by Socrates and has evolved and further developed for 2500 years. Over the years, many researchers proposed various theories on cognitive abilities and the development of critical thinking. Perhaps one of the most well-known is that of Jean Piaget; he believed that abstract thinking, which is needed for critical thinking, did not develop in children until twelve years. There has been recent research documenting abstract thinking at a much younger age (Bloom, 2000; Mills, 2013). Genes may set the upper limit for intelligence, but recent developments in the field of working memory and brain plasticity may be able to overcome these genetic limits (Sousa, 2001).

Students need to have sufficient critical thinking skills to be successful in school, and recent research has established that higher critical thinking skills are associated with job performance and more favorable real-world outcomes (Butler, 2012; Nirmala & Kumar, 2018; Paul, 2005). Although it is possible to increase critical thinking skills through education (Murphy et al., 2014), critical thinking does not improve as a byproduct of the current educational system (Evens et al., 2014; Jones, 2007; Pascarella et al., 2011). When students receive intentional, explicit critical thinking instruction, they can increase their critical thinking disposition and the application of critical thinking (Phelan, 2012). To develop critical thinking skills, individuals need to be able to assess their own reasoning. By explicitly infusing the intellectual standards into individuals' thinking, with practice, these standards can become a part of an individual's

inner voice, and the quality of reasoning can be improved (Elder & Paul, 2008; Paul & Elder, 2006). The intellectual standards are as follows: clarity, accuracy, precision, relevance, depth, breadth, logic, significance, and fairness (Paul & Elder, 2018). Critical thinking skills learned in one class could have a marked effect on the students' long-term critical thinking skills (Tiwari et al., 2006).

In order for students to learn critical thinking skills, teachers need to be able to teach critical thinking skills effectively. Teachers need knowledge of what critical thinking is and need to develop a pedagogical practice in order to teach it effectively (Facione, 1990). Without instruction on how to effectively teach critical thinking skills, educators are not prepared to competently infuse critical thinking into their classrooms (As'ari et al., 2017; Geçit & Akarsu, 2017). Professional development that is of high quality, widely available, has flexible scheduling, and allows faculty to be exposed to evidence-based effective instruction can increase teachers' pedagogy and increase the quality of their instruction (Wynants & Dennis, 2018). The professional development selected for this study was chosen because it met the above requirements according to the literature. The professional development in this study has the goal of educating teachers on how to infuse critical thinking into their instruction to help increase the critical thinking skills of students.

This chapter is concentrated on the following categories (a) theoretical framework, (b) the evolution of critical thinking, (c) the development and characteristics of critical thinking skills, (d) learning to think critically, (e) the importance of critical thinking, (f) critical thinking disposition, (g) critical thinking and education, and concludes with an overview of (h) critical thinking professional development and assessment.

Theoretical Framework

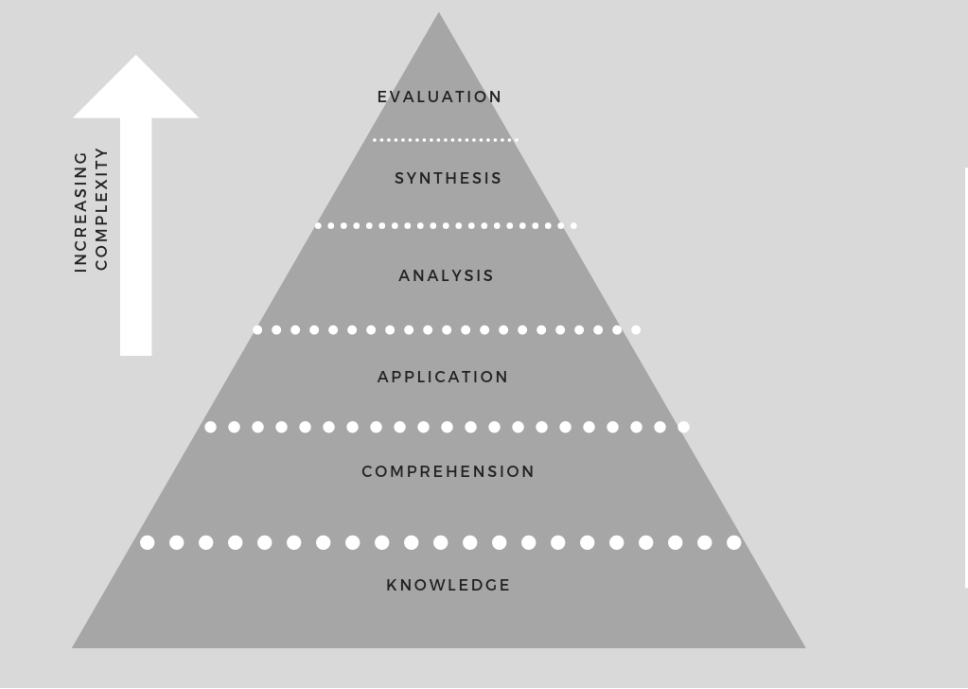
"Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action" (Paul & Nosich, 1992, p. 28). The origin of critical thinking can be traced back 2500 years ago when Socrates developed a method of questioning people who could not rationally justify their claims. The Socratic Method demonstrated that being in a high-power position does not mean that the person has sound knowledge or insight (Paul et al., 1997). By questioning common beliefs and explanations, Socrates helped individuals differentiate those beliefs that were held illogically due to vested interests from those that were based in reasonable and sound logic (Paul et al., 1997). The root meaning of critical thinking comes from ancient Greek. The word 'critical' stems from "kriticos" (meaning discerning judgment) and "kriterion"(meaning standards); therefore critical thinking means a discerning judgment based on standards (Paul et al., 1997).

The Socratic approach engages students in critical thinking by having them examine their current beliefs and guides them to a higher level of understanding of the subject (Magee, 1998; Sigel, 1984). In order for the Socratic questioning to be meaningful, the student must first know about the topic (Merritts & Walter, 2018). To achieve this level, Bloom (1956) founded a taxonomy with the goal of moving students through six levels of thinking skills, the highest of which creates a higher level of thinking. This study uses the concept of higher order thinking skills and, more specifically, the application of critical thinking skills grounded in Bloom's Taxonomy.

In 1948, at the Convention of the American Psychological Association, Bloom and a group of educators began an eight-year process working to develop the cognitive domain known as Bloom's Taxonomy. This lays out the basis for the hierarchy of six levels of thinking, including knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom, 1956).

Figure 1

Bloom's Taxonomy



Note: The hierarchy of the cognitive domain of Bloom's Taxonomy (Bloom, 1956). Used with permission from Virtual Library, 2020; see appendix K.

Knowledge. Knowledge is the first and lowest level in the hierarchy, which includes situations and behaviors that focus on remembering via recall or recognition (Bloom, 1956). This may include recalling specific pieces of information, terms, or symbols. The first part of Bloom's taxonomy also includes knowledge regarding events, dates, people, or other precise information

or basic elements (Bloom, 1956). This is the recall of semantic memory where all that is required to summon this knowledge is to recall it from long term memory in the same form it was learned (Sousa, 2001). When students are assessed about whether they can recall or recite specific facts, they are being tested on their knowledge; this is also often described as rote memorization (Bloom, 1956). This level is the foundation for more complex levels in the hierarchy (Bloom, 1956).

Comprehension. This is the initial level that involves understanding or comprehending. When individuals explain the facts or compare the definitions, they can move to this next level of understanding (Anderson et al., 2001). Going beyond rote memory, this involves individuals understanding the material not just recalling it from long term memory (Sousa, 2001). This level involves rearranging or extending information by using the original details (Bloom, 1956).

Application. When students master the parts of the taxonomy, including knowledge, comprehension, and through understanding, they then apply the information to new situations, which is the third level of Bloom's Taxonomy (Anderson et al., 2001; Bloom, 1956, Sousa, 2001). At this level, students apply their knowledge in specific situations in the form of rules, of procedures, or general ideas. This level requires the individual to activate procedural memory and convergent thinking to apply information to complete a new task (Sousa, 2001).

Analysis. The fourth level of Bloom's taxonomy is analyzing the information, which requires the individuals to gather valid evidence with the goal of reaching a conclusion. This level requires the individual to break up information into parts to understand the structure fully (Sousa, 2001). The main components include analyzing relationships, elements, and organizational principles. Individuals are able to organize and reorganize information in the brain's frontal lobes using metacognition in their thought process (Sousa, 2001).

Synthesis. The fifth level of the cognitive domain is defined as putting elements together to form a whole in a way that constitutes a new pattern or structure (Bloom, 1956). Synthesis entails recombining prior knowledge, experiences, and multiple sources to creatively construct a product (Bloom, 1956). Synthesis is not a simple recombination of fact, but a unique and original process (Wang, 2017).

Evaluation. The next level is evaluating in which the individual makes a decision using the evidence gathered. Evaluation is defined as making judgments and assessing the value of ideas, solutions, methods, arguments, or ideas (Bloom, 1956; Wang, 2017). The highest level of the taxonomy uses distinct criteria in a highly conscious manner and based on the comprehension and analysis of the phenomena (Bloom, 1956). In this level, the individual examines criteria and selects which is most pertinent to the situation, which requires a high level of cognition (Sousa, 2001).

Socratic questioning focuses on developing the higher order thinking skills, which encompass the last three steps in thinking, according to Bloom's taxonomy (Bloom 1956). However, there needs to be a discussion of the distinction between higher order thinking versus critical thinking and how they are related. The three most common terms, often used interchangeably when discussing critical thinking, are creative thinking, problem-solving and higher-order thinking; although they are closely related, there are slight differences in these terms (Facione, 1990; Smith & Szymanski, 2013; Wang, 2017).

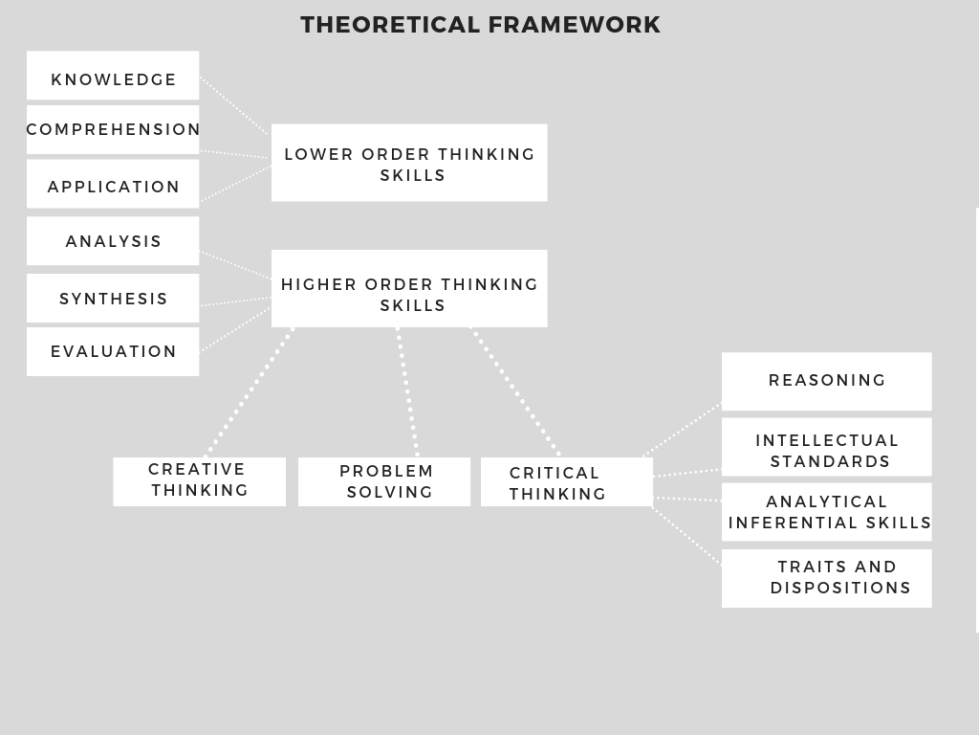
Higher order thinking skills involve the top three levels of Bloom's Taxonomy, including analysis, evaluation, and synthesis, while knowledge, comprehension, and application are considered lower order thinking skills (Anderson et al., 2001). Higher order thinking skills cover a broad concept and often encompass problem-solving, creative thinking and critical thinking

skills (Brookhart, 2010; Lewis & Smith, 1993). When individuals look to solve a problem, they need to assess the context of the problem and examine the many possible solutions, which is using problem-solving skills; they may need to find a new solution, one which has not been defined, which is using their critical thinking skills. In all of these aspects, individuals are using their critical thinking skills, which are embedded into creative thinking and problem-solving (Lewis & Smith, 1993; Newmann, 1991; Resnick, 1987; Wang, 2017). By mastering the levels of Bloom's Taxonomy, students can build their mastery of skills and increase their critical thinking level. In the study by Suprapto et al. (2017), the authors found that higher order thinking skills are essential when it comes to competition and problem-solving in the workplace and career success.

Figure 2 illustrates a more in-depth presentation of critical thinking skills. Critical thinking skills include skills broadly classified in top levels of Bloom's Taxonomy, including interpreting, analyzing, synthesizing, and evaluating (Bloom, 1956; Wang, 2017). Interpretation includes identifying, categorizing, decoding significance, clarifying meaning, and paraphrasing arguments (Facione, 1990; Wang, 2017). The analysis portion of critical thinking includes making inferences about implicit premises, identifying assumptions, and finding flaws in the argument. When the hierarchic interrelation is discovered, synthesis occurs. Evaluation occurs when the structure of the argument is examined for any assumptions, strengths, weaknesses, and uses elements of reason to evaluate the argument (Wang, 2017).

Figure 2

Theoretical Framework



Note: Figure 2 includes the created theoretical framework which is adapted from the cognitive domain of Bloom's Taxonomy (Bloom 1956) with the four major components of critical thinking (Paul et al., 1997).

To further expand on the concept of critical thinking skills, Paul et al. (1997) included four major components including reasoning, intellectual standards, analytical inferential skills, traits and dispositions (Paul et al., 1997). These skills are encompassed in the top three levels of Bloom's taxonomy and are higher order thinking skills, and Paul et al. (1997) examined critical thinking skills in depth, as seen in Figure 2. The first core component, according to Paul et al. (1997), is reasoning; the underlying assumption of a functioning democratic society is the ability to engage in reasoned discourse. To be proficient in analyzing arguments, individuals must be aware of the eight elements of reasoning which include point of view, purpose, concept, question, assumption, question, inference and implication (Paul & Elder, 2013). The reasoning

occurs in the context of intellectual standards, which encompass accuracy, precision, relevance, clarity, logic, breadth, and depth (Paul et al., 1997). Analytic inferential skills include the ability to formulate and assess goals, information, problems, data, assumptions, consequences, frames of reference, and varied points of view (Paul et al., 1997). While analysis explores how arguments are broken down into parts, inference concerns the skills needed to make extrapolations about implicit premises, conclusions, and assumptions (Wang, 2017).

The last interconnected concept is a commitment to specific traits and dispositions such as intellectual courage, humility, empathy, integrity, fair-mindedness, perseverance, and faith in reason (Paul et al., 1997). The development of a critical thinking disposition allows individuals to apply critical thinking appropriately in everyday situations (Facione, 1990). To be an active critical thinker, individuals need to have a critical thinking disposition, which allows them to think critically and productively about issues; without the willingness to think about difficult issues, having the skill to evaluate them is not helpful (Norris, 1985). Critical thinking disposition is the ability to use critical thinking when needed (Facione, 1990). Individuals with higher critical thinking skills have a greater disposition toward critical thinking attributes such as a keenness of mind, a probing inquisitiveness, a zealous dedication to reason, and an eagerness for reliable information (Facione, 1990).

> It is important to note that these components are interrelated and inter-dependent, functioning as a complex of skills, practices, disposition, attitudes, and values. Further, this concept of critical thinking is multi-dimensional, including the intellectual (logic, reason), the psychological (self-awareness, empathy), the sociological (the socio-historical context), the ethical (involving moral norms and evaluation), and the philosophical (the meaning of human nature and life). As the multi-faceted, multi-

> dimensional nature of the core concept of critical thinking has been delineated, it should be increasingly apparent that it can be approached both as a universal ideal and as an intensely personal undertaking. It is the ideal that guides the individual as he/she is engaged in the process of becoming a critical thinker. However, the thinking person is in a dynamic relationship with the ideal, discovering its deeper meaning in the process of experimenting with and living it. This is part of what it means to be engaged in a unique educational process leading to a broadly disciplined human mind and character. (Paul et al., 1997, p. 12)

The Evolution of Critical Thinking

The early origins of critical thinking date back 2500 years ago to Socrates in ancient Greece. Socrates developed a procedure for questioning those who could not rationally justify their beliefs (Paul, 1997). Socrates proposed that even those in authority may not base their beliefs on sound knowledge and established a way to question ideas to deem them worthy of becoming a belief. This included questioning one's beliefs, seeking evidence, examining assumptions, analyzing basic notions; this process is now known as Socratic questioning and is a well-known method of teaching critical thinking to this day (Paul, 1997). Plato and Aristotle were students of Socrates. In Plato's Theaetetus, he wrote of reflective thinking in terms of critical thought through examining one's thought process. Aristotle wrote, "It is the mark of an educated mind to be able to entertain a thought without accepting it" (McKeon, 1941). Thomas Aquinas, who emerged in the middle ages, wrote of the need to be aware of the power of one's reasoning and the philosophy that reasoning needed to be methodically and carefully developed. In 1605, the philosopher Frances Bacon advanced the concept of critical thinking by writing that the mind should not be left to its natural tendencies, as the mind, left unchecked could develop

bad habits of thought and lead to false beliefs (Paul, 1997). This would later lead to the development of the habits of mind and critical thinking dispositions. Francis Bacon was also the first scholar to propose what today is known as the scientific method. Fifty years later, Rene Descartes wrote the process of thought in that every part of thinking should be doubted, questioned and tested in a systematic way to discipline the mind and create sound thinking (Anderson, 2003).

In the early 1900s, John Dewey expanded critical thinking, or as he called it reflective thinking, by including thought as part of human behavior and creating a systematic approach to thinking. He defined reflective thinking as "active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends" (Dewey, 1910, p. 6). Dewey stressed that belief should be established based on a solid set of reasoning. He wrote if knowledge is accepted at once, there is no refection which leads to faulty beliefs. His idea of reflective thinking includes systematic doubt and inquiry with the goal to overcome the force that compels people to accept what they hear at face value as truth and fact (Wang, 2017).

In 1941, Glaser created the Watson-Glaser Thinking Appraisal, the first test for critical thinking skills. His assessment of critical thinking skills included the foundational definition and twelve aspects those with critical thinking should possess, including "(a) to recognize problems; (b) to find workable means for meeting those problems; (c) to gather and marshal pertinent information; (d) to recognize unstated assumptions and values; (e) to comprehend and use language with accuracy, clarity, and discrimination; (f) to interpret data; (g) to appraise evidence and evaluate statements; (h) to recognize the existence of logical relationships between propositions; (i) to draw warranted conclusions and generalizations; (j) to put to the test the

generalizations and conclusions at which one arrives; (k) to reconstruct one's patterns of beliefs based on wider experience; and (l) to render accurate judgments about specific things and qualities in everyday life" (Glaser, 1941, p. 6).

In 1956, Bloom's taxonomy was created and incorporated critical thinking skills in the hierarchy and stressed their application in the importance of education. Robert Ennis continued the work of Dewey and Glaser by emphasizing decision making as the objective of critical thinking; deciding what to believe or do is the goal of critical thinking (Wang, 2017). He stressed that students need guidance on how to develop the skills of being a reasonable and reflective thinker. In the 1980s, The American Philosophical Association asked Peter Facione to examine the state of critical thinking and to determine the goals for teaching and assessing critical thinking skills in students. He assembled a 46-member panel, and in 1987 they came to a consensus for critical thinking: a "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as an explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based" (Facione, 1990, p. 3). In the early 2000s, Paul and Elder developed a process that included individual elements of thought and habits of mind that can be implemented in order to effectively become a critical thinker (Elder & Paul, 2008).

The Development and Characteristics of Critical Thinking Skills

To engage in critical thinking, students need to do more than acquire knowledge; they need to develop a deeper understanding and be able to use knowledge in many settings. Brain scans reveal that as problem solving tasks become more complicated, different parts of the brain are accessed. Plasticity is the ability of the brain to continue to change and develop. There are critical periods of development for some skills; for example, children learn language best from

birth to five years of age, and then another window of opportunity occurs from 10-12 years of age; the brain has greater plasticity for language at these ages (Newport et al., 2001; Sousa, 2001). Among many theories on cognitive abilities, one holds that genes may set the upper limit for intelligence, but brain plasticity may be able to overcome these limits.

There are many theories of cognitive development in children; perhaps the most well-known is that of Jean Piaget. Piaget believed that abstract thinking, which is needed for critical thinking, did not develop in children until twelve years. There has been recent research documenting abstract thinking at a much younger age (Bloom, 2002; Mills, 2013). In order to engage in critical thinking, individuals need to engage their working memory. Working memory occurs in the frontal lobes of the brain and is the conscious process where building, taking apart, or reworking ideas occur (Sousa, 2001). Memory capacity increases as children age, so it is logical to conclude that children's critical thinking ability increases as they age (Byrnes & Dunbar, 2014).

The prefrontal cortex is where the integration of information, planning, and thinking takes place. Scientists who study the physiology of how the brain functions when thinking have discovered that the brain's frontal lobe can be engaged by incorporating elaborative rehearsal involving higher order thinking skills (Awh et al., 1995; Cole et al., 2010; Kelly et al., 2006). "This engagement helps learners make connections between past and new learning, creates new pathways, strengthens existing pathways, and increases the likelihood that the new learning will be consolidated and stored for future retrieval" (Sousa, 2001, p. 266). Elaborative rehearsal involves the learner engaging in complex thinking processes that do not involve memorizing information exactly as learned, which is rote rehearsal, connecting relationships between previous learning to new learning, and assigning meaning (Sousa, 2001).

Stanovich (1999) categorized thinking as a dual process in the terms of System 1 and System 2. System 1 thinking is unconscious, fast, automatic, independent of cognitive ability, contains biased responses, intuitive and is used for most everyday situations and tasks (Byrnes & Dunbar, 2014; Evans & Stanovich, 2013). System 2, which is slower and encompasses critical thinking, includes logical, open minded, controlled, abstract, conscious, detached, reflective metacognitive thinking (Byrnes & Dunbar, 2014). System 1 does not require the use of working memory, whereas System 2 does require the use of working memory (Evans & Stanovich, 2013). Working memory includes a conscious process where building, taking apart, or reworking ideas occur (Sousa, 2001). System 1 thinking, being automatic, can be in direct conflict and overrule System 2 thinking. In 2005, Sugelsand and Dunbar examined neuroimaging and belief bias. They discovered prior held beliefs that participants thought were more plausible had the ability to bias how their brain processed information. When information was inconsistent with participants' prior held beliefs, the brain blocked the information from being processed (Fugelsang & Dunbar, 2005). These biases can encumber effective reasoning. When participants actively engaged in System 2 thinking, reasoning performance increased. When individuals question or do not passively accept information as true is a sign of critical thinking. Recognizing flaws in arguments or reasoning can aid individuals to avoid being persuaded into believing a false belief or argument (Byrnes & Dunbar, 2014).

In the article by Alexander (2014), 18 experts in various fields from education, psychology, and neuroscience, gathered to discuss what critical thinking meant. Combining that with the study by Byrnes and Dunbar (2014), the characteristics of critical thinking were determined to be as follows. Critical thinking requires metacognitive and reflective thinking. Reflective thinking involves individuals analyzing and evaluating their own thinking

(Ghanizadeah, 2017). It is more than formulating an argument or understanding others' arguments. This type of thinking is time consuming, mentally taxing, and involves directed effort. Critical thinking is evaluative and involves the ability to think about the soundness of an argument and the quality of the evidence presented. In order to engage in critical thinking, an individual acknowledges personal bias. Critical thinking is analytical and involves not just examining evidence, but the elements that make up the evidence. Another feature of critical thinking is that it is open minded in that individuals have a heightened awareness that they are capable of making erroneous assumptions. Individuals are open to the fact that other perspectives may be better and more accurate than their own.

Learning to Think Critically

Critical thinking has many definitions, but universally, most researchers agree that critical thinking includes a student who is routinely inquisitive, open to reason, flexible, and rational with regards to evaluation. They are honest when it comes to personal biases, methodical about complex matters, assiduous in seeking applicable information, sensible in making decisions, willing to change their mind, able to select relevant data, determined and persistent (Facione, 1990).

Being able to personally assess one's own reasoning is a fundamental skill of critical thinking (Paul & Elder, 2006). In order to effectively assess reasoning, there are eleven intellectual standards that should be infused into individuals' thinking. When taught these standards explicitly, these standards, with practice, can become a part of an individual's inner voice, and the quality of reasoning can be improved (Elder & Paul, 2008; Paul & Elder, 2006). The intellectual standards are as follows: clarity, accuracy, precision, relevance, depth, breadth, logic, significance, and fairness (Paul & Elder, 2018). Understanding what is being said is the

essential standard of clarity. If the statement or argument is unclear, no other intellectual standard can be applied as it is not possible to determine if the statement is relevant or accurate if it is not understood (Paul & Elder, 2006). The second intellectual standard is accuracy. Critical thinkers approach statements and arguments skeptically; they determine if the statement is true or to what extent are parts of the statement true. This skepticism applies to the individual's thoughts and statements also. It is often the case that individuals tend to believe statements they already agree with or believe; by consciously assessing information for accuracy, critical thinkers can assess statements even if they go against the individual's beliefs (Paul & Elder, 2006). Precision refers to having enough specific detail about the statement or argument to understand it fully; it is obtaining the necessary level of detail. Accurate reasoning requires exploring relevance by staying on track and making sure the idea, facts, or questions are pertinent or applicable to the problem or issue to be solved. Depth encompasses getting beneath the surface of a problem by identifying the complexities and implies meticulousness in thinking. Breadth includes examining multiple viewpoints and maintaining a broadminded perspective, entertaining viewpoints other than the natural viewpoint of the individuals. Logic in reasoning consists of making sure there are no contradictions and using sound judgment and being reasonable. "When one thinks, a person brings a variety of thoughts together into some order. When the combination of thoughts is mutually supporting and makes sense in combination, the thinking is logical" (Paul & Elder, 2013a, p. 33). Significance refers to making sure thinking is focused on the most essential information and takes into account the most important facts and details. Fairness in thinking means that the reasoning is free from bias, self-interest, deception, including self-deception.

Accessing the intellectual traits during the thinking process helps individuals become habitual critical thinkers. It allows them to increase their analytical and evaluative reasoning, inference, interpretation, and decision-making skills. Analytical reasoning skills enable people to identify assumptions and claims and how they interact to form an argument. This is using the intellectual standards of accuracy, precision, and relevance. Interpretation includes interpretative skills that are accessed to discover the context, significance, and meaning of information. These skills use the standards of relevance, logic, and significance. Inference skills enable students to draw conclusions from evidence or facts. Evaluation consists of evaluative reasoning skills which are used to assess the credibility of claims and presented information while determining the strength of arguments (Insight Assessment, 2019). Explanation includes explanatory reasoning skills accessed before making a final decision. At the same time, induction consists of decision-making skills based on drawing inferences about what an individual thinks is true based on data, patterns, experiences, and behaviors (Insight Assessment, 2019). Deduction is related to induction, yet it includes decision making skills that are based on rules, values, policies, and procedures and are logical and clear cut (Insight Assessment, 2019).

The Importance of Critical Thinking

One of the most important goals of education is to impart to students the capacity to think critically (Glaser, 1984; Ku, 2009; Murphy et al., 2014, Schneider & Miller, 2005). Critical thinking involves specific decision-making skills that allow individuals the ability to engage in unbiased reasoning using logical, systematic modes of thinking (Ennis, 1985; Facione et al., 1996). Thinking skills are used in most academic disciplines and are required to meet the necessary academic objectives for success (Facione et al., 1996; Sherblom, 2010). Higher education scholars agree that deep and rational thought should be the standard of academic

excellence and should be an integral part of student's individual, social, and academic lives (Heinrich et al., 2015; Koenig, 2011; Nirmala & Kumar, 2018; Scriven & Paul, 2004).

Recently researchers have looked at the relationship between critical thinking, achievement, and real life settings. Critical thinking skills have been linked to predicted real world outcomes (Butler, 2012; Dwyer et al., 2012). Researchers found that individuals that reported fewer adverse life events had higher critical thinking skills (Butler, 2012; Butler et al., 2017). In a study by Samanci (2015), a statistically significant positive relationship was found between moral judgment aptitudes and critical thinking abilities. Critical thinking skills predicted life events more accurately than intelligence (Butler et al., 2017). Individuals that have higher critical thinking skills may more easily avoid negative life events (Franco & Almeida, 2015). Critical thinking is positively correlated to achievement; students with higher critical thinking skills have a higher achievement (Ghanizadeh, 2017; Ramsey & Baethe, 2013; Schneider & Miller, 2005). Solon (2003) found that the more critical thinking instruction students receive, the better they improve their critical thinking skills. When students can think critically using skills like analyzing and critiquing information at a high level, they can engage in more in-depth and more sophisticated problem-solving strategies, which helps them to be more efficient in their academic studies (Ghanizadeh, 2017; Ramsey & Baethe, 2013).

Studies have solidified the fact that active critical thinking is a vital part of creating a successful student and member of society (Heinrich et al., 2015; Williams, 2005). Critical thinking skills help to engage thinking by analyzing issues, examining evidence and problems, questioning assumptions, while simultaneously identifying data that is relevant to the situation at hand (Rhodes, 2010). Williams (2005) writes that "although critical thinking is not the total answer for societal problems, thinking that is loose, prejudicial, or ill-informed will undoubtedly

undermine society's potential to be more productive and humane" (p.164). Students need to understand fact vs. opinion-based sources and be able to differentiate between distorted, exaggerated, and incomplete information (Williams, 2005). To develop critical thinking skills, students need to develop the skills to deconstruct a problem and find a solution free from their personal bias (Van Der Werff, 2016). An essential aspect of critical thinking is developing individuals who can think critically, analyze evidence, and ascertain the validity of evidence and logically determine a legitimate conclusion (Williams, 2005). The quality of a conclusion is based on the quality of the information. Therefore, it is essential to teach students how to find credible information to form valid conclusions (Williams, 2005). Williams (2005) writes that the most "persistent tendencies undermining critical thinking at a societal level is the failure to seek information about an important issue from the most expert sources on that issue" (p.186). Students need to use critical thinking skills to be able to question and discuss ideas and issues in their daily lives to help them evolve into conscious citizens with democratic decision-making skills from a critical perspective (Samanci, 2015).

A sign of quality higher education is producing students who have developed proficient critical thinking skills (Schneider & Miller, 2005; Scriven & Paul, 2004). College graduates lack critical thinking skills, and this can put them at a disadvantage for jobs and future success (Quitadamo et al., 2011). College students are graduating from college without the higher order thinking skills needed (Nirmala & Kumar, 2018; Smith & Szymanski, 2013). Many students are unprepared with regard to reading and writing skills required at the college level (Evens et al., 2014; Lennon, 2014; Marin & Halpern, 2011). The American Diploma Project discovered in the United States that most students do not acquire the abilities or knowledge to be successful in college or the workplace (Achieve, 2004). Employers want college graduates who can

demonstrate critical thinking skills. However, a mere 6% of college graduates are adept in critical thinking skills, even though 87% thought their colleges had prepared them regarding critical thinking skills (Business-Higher Education Forum, 2003). Eighty-two percent of college faculty were dissatisfied with their students' ability to critically think (Achieve, 2014). High school graduates need to be able to use higher order thinking skills, including judging the credibility of sources, evaluating the argument and interpreting and synthesizing information to make valid and correct decisions to succeed as adults (Achieve, 2004). Lower order thinking skills require the mechanical or routine application of memorized information and formulas (Bloom, 1956; Smith & Szymanski, 2013). Higher order thinking skills, however, require an individual to take the new information they are given and access information that was stored in their memory and assimilate both origins of information and draw conclusions (Bloom, 1956; Husamah et al., 2018; Smith & Szymanski, 2013). The more higher-order thinking questions students are asked, the greater the gains in their critical thinking skills (Renaud & Murray, 2007).

Critical Thinking Disposition

Critical thinking disposition is the tendency to use critical thinking skills (Stedman et al., 2009). Both thinking style and critical thinking disposition combined underline an individual's habits of thought (Emir, 2013). Critical thinking disposition includes positive habits of the mind, such as being confident, judicious, inquisitive, organized, analytical, intellectually honest, and tolerant (Facione et al., 1996). Having a positive critical thinking disposition means actively and consistently using one's critical thinking abilities in judging what to or what not to believe in any situation (Ennis, 1985; Facione et al., 1996). It is an internal motivation that drives an individual and includes traits such as truth-seeking, open-mindedness, analytical and systematic tendencies,

inquisitiveness, and maturity (Emir, 2013). The motivation to think is as essential as the ability to think (Emir, 2013; Facione et al., 1996).

Critical thinking disposition is just as or more important than critical thinking skills themselves (Facione et al., 1996; Stedman et al., 2009). Today's society is under accelerated change with a multitude of informational sources continually streaming in our personal and civic lives (Facione et al., 1996). To be able to decipher truth from fiction, individuals need to be willing to think critically. To be successful students and members of a workforce, individuals need to be inclined to make "informed, fair-minded, judgments in contexts of relative uncertainty about what to believe and what to do in a variety of situations" (Facione at al., 1996, p. 1). Citizens must be willing to engage their critical thinking skills in a successful society (Facione et al., 1996).

An essential education goal at any level should be to further students in developing critical thinking skills and dispositions (Halpern, 1998; Facione, 1990; Turan, 2016). A proficient critical thinker engages in critical judgment and encourages others to do so also (Facione, 1990). Having a skill means being able to use the skill correctly at the correct time; therefore, if an individual is skilled at critical thinking, the individual knows the procedures and how to apply them (Facione, 1990). A school culture that fosters critical thinking changes the disposition the students have towards critical thinking; it changes the way they see knowledge, how it is assimilated, and the part they play in their personal learning process (Tsui, 2008).

Even when individuals are educated with the skills needed to apply critical thinking skills, it does not necessarily translate into the use of those skills (Nicholas & Raider-Roth, 2016). If students do not develop a positive critical thinking disposition, they tend not to apply their critical thinking skills. Duchscher (2003) discovered that even when participants could

define critical thinking very quickly, they did not apply it in their everyday lives. Even with the understanding and background education in critical thinking, students did not readily engage in metacognition or analyze their thinking (Duchscher, 2003). Even after being taught critical thinking skills and how to apply them, individuals did not readily connect the relationship between an attitude of inquiry and critical thinking (Duchscher, 2003). To encourage individuals to use and apply their critical thinking skills, there needs to be an attitude of inquiry that is encouraged by their mentors (Duchscher, 2003). Critical dialogue, although it challenges existing knowledge, is essential to develop individuals that can apply high-level critical thinking skills in their daily lives (Duchscher, 2003).

Critical Thinking and Education

A focal goal of the educational system is to increase critical thinking skills in students. Yet, there is little agreement on how to best educate students in a manner that improves critical thinking skills (Marin & Halpern, 2011). The development of critical thinking skills is not solely dependent on the instructional technique or course content (Tsui, 1999). Solon (2003) found that the more critical thinking instruction students received, the better they improved their critical thinking skills. Critical thinking requires training, patience, practice, and actively engaging students using questioning techniques to encourage investigating information and applying knowledge (Snyder & Snyder, 2008). Student engagement in mental activities should go beyond concrete knowledge in order to increase critical thinking skills (Sigel, 1984). Individuals' critical thinking can increase when they are actively engaged in activities infused with critical thinking skills (Snyder & Snyder, 2008).

It is possible to foster the growth of critical thinking skills in the home and school experiences (Murphy et al., 2014). Pedagogical or intervention methods designed to help

students identify complex concepts require significant, multilayered examination and help them to look for various forms of evidence to justify their decisions, which further develops their critical thinking skills (Murphy et al., 2014). Tiwari et al. (2006) showed that the critical thinking skills learned in one class could have a marked effect on the students' long-term critical thinking skills. Tsui (1999) suggests that identifying instructional techniques that can be taught to instructors can help the academic community to implement changes focused on increasing students' critical thinking skills.

Critical thinking skills do not improve extemporaneously as a byproduct of education, and furthermore, many students do not improve or only marginally expand their critical thinking skills during their college years (Evens et al., 2014; Jones, 2007; Pascarella et al., 2011). There is a limited amount of growth in critical thinking levels, specifically in university students (Evens et al., 2013; Pascarella et al., 2011). The nominal growth in critical thinking skills during the first year of higher education is also evidence that teaching critical thinking skills is not transpiring in the first year of college courses (Evens et al., 2013, 2014). When looking at the development of critical thinking, Evens et al. (2013) found a small but significant increase in students' critical thinking skills when comparing the beginning to the end of their first year of higher education. Evens et al. (2013) discovered that students who had a mainly academic background with regards to secondary education significantly outperformed students whose secondary education focus was more on artistic or technical aspects. Furthermore, Evens et al. (2013) observed students who entered higher education with higher critical thinking skills instilled during their secondary education showed more advancement in critical thinking skills throughout their first year of college.

Critical thinking skills can be acquired and in a relatively short period using a curriculum that explicitly teaches critical thinking skills (Cone et al., 2016; Gupta et al., 2015; Heijltjes et al., 2015). When individuals learn critical thinking skills explicitly, it has a significantly positive impact on their critical thinking skills (Facione, 1990; Sanavi & Tarighat, 2014). Explicitly learning critical thinking skills comprises direct instruction with a significant amount of guidance where the teacher instructs students in a way that teaches independent cognitive skills and specific actions the students can rehearse (Cordingley et al., 2005; McGuinness, 1999). This type of effective critical thinking learning has a structure that includes active engagement where a specific skill is presented, followed by deliberate practice, and lastly, allows the students an opportunity to transfer the information (Marin & Halpern, 2011). Explicit critical thinking learning emphasizes why, when, where, and how to apply each of the cognitive skills (Ku et al., 2014). Direct instruction occurs when the skill to be learned is demonstrated, then the student practices that specific skill, and lastly, there is an independent assessment of that skill (Ku et al., 2014). This method can be used as a complement to conventional education, and an overhaul of the curriculum is not needed (Marin & Halpern, 2011).

Students that explicitly learn how to critically think, understand, and integrate the steps of why, where, when, and how to use each cognitive skill, can develop stronger critical thinking skills. To further advance individuals' critical thinking skills, data flow should be structured by breaking the problem up into smaller fields to help students identify the data that is useful in forming their decision (Parrott & Rubinstein, 2015). These iterative skills include amending the original questions, since often the questions students think to ask at the beginning of analysis are not the best questions (Parrott & Rubinstein, 2015). Using iterative skills, the students can modify and reformulate their original questions, which is an integral step to develop critical

thinking skills. Instructional interventions that explicitly teach critical thinking skills while incorporating opportunities for students to practice those skills can increase student critical thinking skills (Heijltjes et al., 2014).

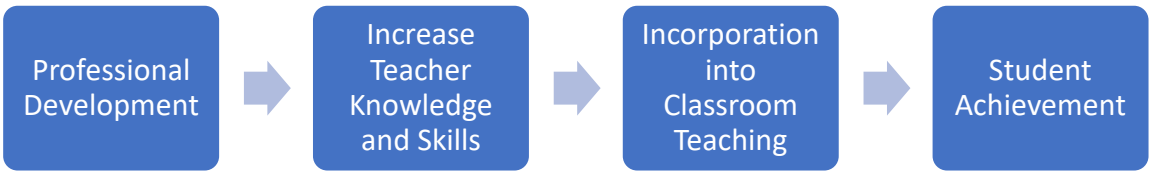
When students learned critical thinking skills explicitly, they showed much more extensive growth in critical thinking skills than students who received embedded-only instruction (Gunn et al., 2008; Marin & Halpern, 2011; Sanavi & Tarighat, 2014; Solon, 2003). Explicit instruction of critical thinking skills also improved students' reasoning performance (Heijltjes et al., 2015), and children who received explicit thinking instruction developed an awareness about their thinking skills (Dewey & Bento, 2009). Pupils who had moderate explicit critical thinking training enhanced their critical thinking skills when compared to students who received no explicit critical thinking instruction (Solon, 2003).

An essential part of learning critical thinking skills is to be able to apply them to other situations. Students can better transfer their critical thinking skills to situations that occur on a daily basis when they receive explicit versus implicit/embedded instruction (Marin & Halpern, 2011). Solon (2003) found that the more critical thinking instructions students received, the better they improved their critical thinking skills; deliberate critical thinking instruction is effective. Embedded critical thinking instruction incorporates skills interlaced throughout the curriculum. In contrast, explicit critical thinking teaching includes lessons that are purposely designed to teach critical thinking skills in a step by step manner. Abrami et al. (2008) found that even immersing students in thought-provoking course content, but not explicitly teaching critical thinking principles, was not an effective way to teach critical thinking skills. Abrami et al. (2008) found the most successful way to impart critical thinking skills is to use explicit training that is separate from the curriculum and then apply the learned skills to the course content.

There have also been contradictory results about the increase in critical thinking skills following explicit instruction. After explicit critical thinking instruction, one study found that there was little to no increase in students' overall critical thinking skills, yet student perceptions of critical thinking did increase (McGuire, 2010). This study had a critical thinking intervention that was one week in duration, which may account for the contradictory results. Other studies where teachers have had more intensive training have shown that students can increase their critical thinking skills (McGuire, 2010). Teachers involved in this study learn to design their lessons in a way that explicitly teaches critical thinking.

Figure 3

How Professional Development Affects Student Achievement



Note: Figure 3 illustrates the hierarchy on how professional development can impact student achievement. The researcher adapted this from synthesis of Yoon, et al., 2007.

Critical Thinking Professional Development and Assessment

If teachers are not taught themselves how to teach critical thinking skills, they may be unable to educate their students on how to excel in and master critical thinking (As' ari et al., 2017; Williams, 2005). Teachers have limited knowledge, lack training on how best to teach, advance and assess critical thinking skills and are therefore unprepared and unskilled at instilling these skills to their students (Al-degether, 2009; Ashton, 1998; Lennon, 2014; Moore & Stanley, 2010; Stedman & Adams, 2012; Whittinghton, 1995). Faculty that had no professional development or formal training in the area of critical thinking attempted to incorporate it in their classes, but without concrete knowledge on how to teach it, the instruction became disjointed and

faceted (Nicholas & Raider-Roth, 2016). Teachers cannot be expected to effectively teach critical thinking skills to students if they have not developed their own higher order thinking skills (Smith & Szymanski, 2013). Teachers that have not been taught how to incorporate critical thinking skills into their teaching effectively are unable to effectively teach students how to apply these skills (Smith & Szymanski, 2013; Whittington, 1995; Williams, 2005).

Professional development is a structured, organized time that provides instructors with the tools they need to expand their knowledge, practice, skill, and effectiveness, so that they can increase student achievement (Darling-Hammond et al., 2017). Valuable professional development is focused on content, integrates active learning activities, reinforces the importance of collaboration, employs scientifically proven curriculum models, provides expert support and coaching, and includes reflection and feedback (Darling-Hammond et al., 2017; Desimone, 2011). Professional development active learning strategies can consist of practicing the material learned, analyzing, or reviewing peer or student work, participating in discussions, and applying new learning knowledge to lesson plans and curriculum development (Whitworth & Chiu, 2015).

Explicit instruction can improve students' reasoning, application of, and dispositions regarding critical thinking skills. When students receive explicit training on how to apply critical thinking skills, students can increase their critical thinking skills (Abrami et al., 2008; Cone et al., 2016; Ghanizadeh, 2017; Solon, 2007). When utilizing explicit critical thinking skills in education, students' reasoning on various tasks increases (Macpherson & Stanovich, 2007; Nisbett & Fong, 1987). Allowing students to practice their skills while using explicit critical thinking instruction further increased students' reasoning skills (Heijltjes et al., 2015; Sanavi & Tarighat, 2014). Students who received explicit instruction regarding thinking skills could apply

thinking skills better than their peers who did not receive explicit instruction even after two years (Dewey & Bento, 2009). When students receive intentional, explicit critical thinking instruction, they can increase their critical thinking disposition and the application of critical thinking (Phelan, 2012). Explicit instruction not only improves critical thinking skills but can be learned in a relatively short time (Abrami et al., 2008; Cone et al., 2016; Heijltjes et al., 2015; Sanavi & Tarighat, 2014). Heijltjes et al. (2015) found that student outcomes did indeed increase when a short explicit critical thinking instructional intervention was integrated into the curriculum. Marin and Halpern (2011) propose the most effective way to foster critical thinking skills in students is using short-term intensive, explicit instruction.

For there to be effective critical thinking, all course content, activities, and teaching procedures need to focus on how they will increase students' critical thinking skills (Nosich, 2005). When instructors receive advanced instruction on the skills and process to teach critical thinking skills, individuals' critical thinking skills improve more than if instructors receive no specialized training or professional development (Abrami et al., 2008). Abrami et al. (2008) found, "To maximize impact requires both the willingness to incorporate critical thinking instruction and explicit strategies and skills to do it effectively" (p. 1121). When educators have clear critical thinking objectives and integrate critical thinking into their courses, students' critical thinking skills improve according to the study by Abrami et al. (2008). The optimal way to advance critical and reflective thinking is by designing a curriculum that applies an activist approach on the part of the instructor (Henderson Hurley & Hurley, 2013).

Professional development that focuses on the subject matter and how students can best learn the content while creating an atmosphere where teachers are involved in active learning, including receiving feedback, analyzing student work, are essential features of effective

professional development (Desimone, 2011). Successful professional development can increase teacher learning and alter teachers' beliefs and attitudes about teaching techniques or curriculum, which can result in a change in the teaching methods and increase student achievement (Whitworth & Chiu, 2015). The content of professional development that is high quality leads to better practices and increased teacher knowledge. High-quality professional development can improve student outcomes (Avalos, 2011; Buczynski & Hansen, 2010; Meiers & Ingvarson, 2005).

The teacher time commitment was of the utmost importance in selecting a professional development plan. Due to the limited free time teachers have, the researcher began to explore the possible option of an online professional development program. Online professional development is flexible and allows for teachers to fit training into their schedules, work at their own speed, and gives them admission to high-quality information including resources that may not be available locally (Dash et al., 2012; Dede et al., 2005; Russell et al., 2009). Customized online professional development allows the teachers to access material that they might never have had access to and can reach a broader audience (Wynants & Dennis, 2018). Teachers who have access to online professional development can choose when to access and participate in the professional development program; this allows them to choose the speed and time frame that is most useful for them (Wynants & Dennis, 2018). When educators have more accessibility to professional development and have flexibility in choosing when and what they are learning, there is a favorable outcome when compared with traditional professional development (Carey et al., 2008; Dash et al., 2012; Shaha & Ellsworth, 2013). Pacing control and flexibility are the two main advantages of online professional development (Wynants & Dennis, 2018).

The fifteen-week professional developments used in this study introduced the elements of reasoning, intellectual standards, and traits via discussion, readings, and applications, including redesigning lessons and learning strategies to consciously use critical thinking concepts throughout their instruction (Foundation for Critical Thinking, 2017). Duration and participation in professional development have been linked to more favorable teacher learning outcomes, and longer durations have better outcomes (Whitworth & Chiu, 2015). To be effective, professional development should include a minimum of 20 hours (Desimone, 2011). Professional development that is only a few hours leaves little time to master new content, practice, and has a smaller effect on teacher growth than professional development with more long-term duration. (Banilower et al., 2007; Gerard et al., 2011). The minimum requirement for professional development in this study was 20 hours, and participants spent, on average, two to three hours per week. The longer the professional development, the more likely follow-up, mentoring and reflection are included in the program (Darling-Hammond et al., 2017).

Faculty need to be educated in critical thinking and incorporate a pedagogical model that focuses on assessment and instruction of critical thinking (Facione, 1990; Nicholas & Raider-Roth, 2016). After reviewing the literature on professional development, a program was sought out that met the above requirements in the literature review. A flexible, online, long term semester wide program was selected that was content focused, had integrated activities, and had the support of the administration. The professional development program selected for this study had the objective to deepen participants' understanding of the foundations of critical thinking and help participants in the program further be able to understand and apply critical thinking skills. An objective of the program selected was to use critical thinking explicitly, and then incorporate elements of reasoning and intellectual standards in developing lessons that could be taught in

their classrooms while fostering critical thinking at every moment in their instruction. First, educators must understand what constitutes critical thinking. Secondly, educators must learn how to successfully teach and integrate these skills into their instruction for their students (Paul, 2005; Whitworth & Chiu, 2015).

Effective online professional development can resemble natural workplace learning and can have a positive learning experience impact on participants (Teräs & Kartoglu, 2017). Having a collaborative experience with colleagues where individuals can learn from others' experiences can enhance the effectiveness of online professional development (Teräs & Kartoglu, 2017). Online professional development can create meaningful ways for teachers to engage in dialog that can help develop their thinking skills (Dede et al., 2005). Online professional development is successful when it is encompassed in an active network of interactions where the learner is actively engaged, collaborating with peers and at the center of the process (Teräs & Kartoglu, 2017). Landry et al. (2009) found that when online professional development is paired with teacher mentoring and detailed feedback on instruction, the most significant gains are seen with regards to teacher behavior and student achievement. Effective online professional development incorporates an interconnected atmosphere and, when paired with a mentor teacher and feedback, can enhance the effectiveness of the online professional development.

Disadvantages of online professional development are lack of social interaction and collaboration, lack of motivation, and lack of accountability (Wynants & Dennis, 2018). Social connection is an important aspect of online professional development and can be remedied by using a discussion board or forum for participants to connect to each other (Wynants & Dennis, 2018). Teachers may not have sufficient time to complete the professional development course, depending on how high the demand for time is. The more time the online professional

development demanded, Cho & Rathbun, (2013) found that enrollment was lower, while at the same time, the teachers that were involved were highly motivated.

The most considerable hindrance to teaching critical thinking was found to be time to prepare, class size, departmental leadership, curriculum structure, the culture of the organization, and the levels of the students (Linthacum, 2011; Nicholas & Raider-Roth, 2016). Other obstacles include students' resistance to new ways of teaching, faculty workload, and lack of knowledge on how to teach critical thinking skills (Al-degether, 2009; Ganapathy et al., 2017; Linthacum, 2011). Although many educators understand the importance of teaching critical thinking skills, they often become discouraged because they can be challenging to implement and often feel time limited (Ganapathy et al., 2017). Al-degether (2009) found that educators that have accurate knowledge of critical thinking do not necessarily use critical thinking methods in their classrooms. Individuals with greater knowledge of critical thinking skills do not necessarily use those skills more often than individuals with lower critical thinking knowledge (Al-degether, 2009). When examining the level of preservice teachers' critical thinking dispositions, it was found they were at a low-level, meaning even if they possess the knowledge of critical thinking skills, they do not apply them (Cansoy & Türkoglu, 2017; Geçit & Akarsu, 2017). Faculty members who were older tended to have a more positive opinion about teaching critical thinking skills than younger faculty members. Faculty's years of teaching experiences did not correlate to levels of critical thinking disposition (Cansoy & Türkoglu, 2017), although a study by Al-degether (2009) found that instructors with more advanced degrees had a more favorable disposition towards critical thinking skills. Critical thinking disposition is essential for teachers to possess if they are to model these skills, which are needed to educate students with regards to critical thinking effectively (As' ari et al., 2017; Facione, 1990).

The assessment used in this study was the California Critical Thinking Skills Test (CCTST). INSIGHT assessments are known worldwide, and their assessment metrics have been scientifically developed over the course of 40 years. The California Critical Thinking Skills Test focuses on the eight subsets of critical thinking (a) overall (b) analysis (c) interpretation (d) inference (e) evaluation (f) explanation (g) induction (h) deduction (Insight Assessment, 2019). The CCTST is based on the APA Delphi conceptualization on critical thinking (Insight Assessment, 2019). The Delphi report included 46 various experts in the field of critical thinking, and it included an agreed upon overall definition of critical thinking (Facione, 1990). The definition developed was as follows: critical thinking is purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based (Facione, 1990).

The APA Delphi report has been endorsed by educators around the world (Facione, Facione, Blohm & Gittens, 2008). The primary use of the CCTST is to "gather valid and reliable data about the baseline, entrance-level, or exit-level critical thinking skills of various groups of people, commonly college level students and working adults" (Facione et al., 2008, p. 11). An optimal way to use the California Critical Thinking Skills Test is when a new curriculum is being explored (Insight Assessment, 2019). The CCTST offers a comprehensive assessment of how well critical thinking skills are being expressed and taught in the new curriculum (Insight Assessment, 2019). In curriculum assessment, the CCTST can be used to pretest the students before they have received any training in the new curriculum and then posttest the students after having received the new curriculum, and from those results, the CCTST can help determine how effective the new curriculum is regarding critical thinking skills (Insight Assessment, 2019). The

individual test scores are reported as a raw overall of critical thinking ability, a categorical interpretation of the strength of the participants' overall score, a percentile ranking compared to other similar test takers, and scale scores which indicate which of the skill areas are strong and weaker and require training attention (Insight Assessment, 2019).

Conclusion

"It is the mark of an educated mind to be able to entertain a thought without accepting it," wrote Aristotle (McKeon, 1941). Using the eleven intellectual standards, individuals can develop and increase their critical thinking (Paul & Elder, 2010). It is possible for students to acquire critical thinking skills in a relatively short period using a curriculum that explicitly teaches critical thinking skills (Cone et al., 2016; Gupta et al., 2015; Heijltjes et al., 2015). Critical thinking requires training, patience, practice, and actively engaging students using questioning techniques to encourage investigating information and applying knowledge (Snyder & Snyder, 2008).

Educators can help their students acquire higher-order thinking skills (Shaha & Ellsworth, 2013) only if they can recognize wherein the standard critical thinking opportunities exist. It is then when a teacher can effectively incorporate critical thinking activities and opportunities in their instruction (Forawi, 2016). If teachers are given the training to teach critical thinking skills, the students can benefit from it for years. When students are taught critical thinking skills in secondary education, the skill stays with them for at least the first year of higher education (Evens et al., 2013). With the growth of online education, teachers now have the ability to participate in high-quality professional development in the area of critical thinking skills. This has the potential to transform the area of critical thinking professional development and student critical thinking skills.

Chapter III

Design and Methodology

Introduction

This study investigated the effect of teacher professional development on students' critical thinking skills. A quantitative between-group research design was chosen to explore the research questions in this study. This chapter provides an overview of the design and methodology for the study, including the research design, description of the teacher and student participants, a detailed description of the data collection methods, analytical methods and concludes with limitations of the study.

Research Design

A quantitative between group research design includes two or more groups, an independent variable that can be manipulated as well as a dependent variable that can be measured in all groups (Creswell, 2015). A quantitative between group research design was selected for this study as the students were part of already intact groups; therefore, random assignment was not possible (Creswell, 2015; Demirbag et al., 2016). This study examined if teacher participation in professional development impacted student critical thinking skills.

The researcher selected participants using convenience sampling as they were willing and able to be studied (Creswell, 2015; Maxwell 2015). When using convenience sampling, the research cannot say with confidence that the participants are representative of the population, yet the sample can offer valuable data to answer questions (Creswell, 2015). The selected student participants were part of previously formed intact classes; therefore, the random assignment of student participants was not possible, hence a quantitative between group design was adopted (Dimitrov & Rumrill, 2003; Creswell, 2015). Student participants included college preparatory,

honors or Advanced Placement junior and senior high school students as the California Critical Thinking Skills Test is designed for individuals in high school college preparatory classes through adults.

The pretest-posttest design was implemented in this study. Pretest-posttest designs are formulated to discover and measure the relationship between the independent and dependent variables (Mertler, 2016). Pretests are used to assess participants on a measure of an attribute or characteristic before intervention occurs while the posttest measures that same attribute or characteristic after the intervention occurs (Dimitrov & Rumrill, 2003; Creswell, 2015). Variation in student pretest scores was controlled for using the pretest as a covariate. The means were adjusted better to assess the difference between the three groups' posttest scores. There were three unique groups, treatment group TG1, treatment group TG2, and the control group CG1 in this study. Teachers from the treatment group TG1 and treatment group TG2 participated in two different professional development interventions. While the intervention groups participated in professional development intervention, the control group CG1 did not participate in any critical thinking professional development intervention.

The relationship investigated was between student participants' critical thinking scores and teacher participation in a professional development intervention or the control group. The interval scale dependent variable was the students' posttest scores, and the independent variable was teacher participation in one of three groups, treatment group TG1, treatment group TG2, or the control group CG1. The testing instrument was the California Critical Thinking Skills Test, which was taken by student participants as a pretest before the intervention and again as a post-test after the intervention.

After the study was complete, the control group teachers were able to access professional development material so all teachers could benefit from the professional development intervention. When the intervention is available to all teachers, including control after the study is completed, this indicates a higher quality study (Creswell, 2015). To measure any change in the critical thinking skills of student participants' posttest scores, the control and intervention groups were compared for statistical significance. The variation in the three groups' pretest scores was controlled by using the pretest scores as a covariate.

Table 1

Study Design

Group	Assignment	Pretest	Treatment	Posttest
TG1	Non R	O_1	X_1	O_2
TG2	Non R	O_3	X_2	O_4
CG1	Non R	O_5		O_6

TG = Treatment Group O = Measures

CG = Control Group X = Treatment

Research Questions

There were five dependent variables for this study based on the student participants' scores on the California Critical Thinking Skills test in overall critical thinking skills, analytical reasoning, inference skills, evaluative reasoning skills, and decision-making skills. The first nominal level independent variable for this study varied over three levels, two treatment groups, and one control group. The second independent variable was dichotomous and varied over two levels, the control and intervention group. Each professional development intervention group will be individually compared to the control group. The research questions for this study are:

RQ1: Does teacher participation in critical thinking professional development impact critical thinking skills of high school students taking college preparatory classes as measured by the overall score on the California Critical Thinking Skills Test?

RQ2: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact analytical reasoning skills of high school students taking college preparatory classes as measured by the analysis subset score on the California Critical Thinking Skills Test?

RQ3: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact inference skills of high school students as measured by the inference subset score on the California Critical Thinking Skills Test?

RQ4: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact evaluative reasoning skills of high school students as measured by the evaluation subset score on the California Critical Thinking Skills Test?

RQ5: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact decision-making skills of high school students as measured by the induction and deduction subset scores on the California Critical Thinking Skills Test?

Hypotheses

H_a1: There will be a statistically significant difference between total pretest scores and total posttest scores on the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

H_01: There will be no statistically significant difference between total pretest scores and total posttest scores on the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

H_a2: There will be a statistically significant difference between the pretest scores and posttest scores on the analytical reasoning subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

$H_0$2: There will be no statistically significant difference between the pretest scores and the posttest scores on the analytical reasoning subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

H_a3: There will be a statistically significant difference between the pretest scores and posttest scores on the inference skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

$H_0$3: There will be no statistically significant difference between the pretest scores and the posttest scores on the inference skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

H_a4: There will be a statistically significant difference between the pretest scores and posttest scores on the evaluative reasoning skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

$H_0$4: There will be no statistically significant difference between the pretest scores and the posttest scores on the evaluative reasoning skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

H_a5: There will be a statistically significant difference between the pretest scores and posttest scores on the decision-making skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

H_05: There will be no statistically significant difference between the pretest scores and the posttest scores on the decision-making skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

Participants

The population of this study included junior and senior advanced level high school students enrolled in college preparatory, honors or Advanced Placement courses. Convenience sampling was used to select participants as they were willing and able to be studied (Creswell, 2015). Although in convenience sampling, the sample may not be representative of the population, the sample can still provide quality data that is useful to answer research questions and hypotheses (Creswell, 2015). The focus of this study included a sample size of 389 student participants from fourteen classes throughout three high schools.

Participants were associated with the dependent variable, the California Critical Thinking Skills test scores, and attended high school as a junior or senior and were enrolled in a college preparatory, honor, or Advanced Placement course**.** The student participants were 49% female and 50% male, and 1% declined to state with an average age of 17 years old.

The following inclusion criteria were used to select the student participants:

- Students enrolled in junior or senior level college preparatory, honor or Advanced placement high school course
- Students enrolled in a semester long 15-week course where their teacher was concurrently enrolled in a minimum of 20 hours of professional development focused on critical thinking instruction

- Students enrolled in a course where they were given one or more opportunities a week to complete activities that incorporated critical thinking skills

Student participants were excluded when their teacher was not able to complete the entire research protocol. Some teachers were unable to complete the research study do to health, other time commitments. If any student did not complete both the pretest and the posttest in entirety, they were excluded from the study. In these cases, student test results were not included in the final study results.

Setting

Three high school sites in the western United States were selected from which teachers and student participants were recruited for this study. Each of the sites offered a minimum of four high level college preparatory, honors or Advanced Placement classes for junior and senior students. By increasing the number of sites selected, it increased the sample size. Larger sample sizes are more likely to be a more representative sample of the target population (Mertler, 2016). Site 1 was a suburban high school which had an average enrollment of 1,200 students, with an ethnic makeup of the student population of Asian-Pacific Islander 15%, Filipino 1%, Hispanic/Latino 10%, African American 1%, White (non-Hispanic) 61%, Multiethnic 10%. Site 1 offered twenty-six Advanced Placement courses, and the school had a 99% graduation rate. Site 2 was a suburban high school and had an average enrollment of 3,500 students. The ethnic makeup of the population was Asian-Pacific Islander 9.4%, Filipino 5.2%, Hispanic/Latino 28%, African American 5%, White (non-Hispanic) 45%, Multiethnic 6%. Overall, Site 2 offered 25 Advanced Placement courses, had 60% of the student population meeting or exceeding state standards, and has a 94% graduation rate. Site 3 was a suburban high school that had an average enrollment of 700 students and offered 25 Advanced Placement courses. The ethnic makeup of

the population was Asian-Pacific Islander 50%, Hispanic/Latino 6%, African American 5%, White (non-Hispanic) 10%, Multiethnic 29%. Site 3 had a 98% graduation rate.

Table 2

Summary Demographics

	Site 1	**Site 2**	**Site 3**
Student Enrollment	1,200	3,500	700
Student Ethnicity			
African American	2%	5%	5%
Asian (includes pacific islander)	16%	15%	50%
Two or More Races	10%	6%	29%
Hispanic or Latino	10%	28%	6%
White alone, not Hispanic or Latino	60%	45%	10%
Other	2%	1%	

Institutional Review Board (IRB) approval was gained through Northwest Nazarene University and school sites granted permission to recruit participants. To safeguard participants' privacy and treatment in the research process and beyond, the researcher completed training and was certified by the National Institute of Health in human research. (see Appendix J).

Professional Development Interventions

The professional developments for this study included material based on the research of Dr. Richard Paul and Dr. Linda Elder, both experts in the field of critical thinking. Dr. Richard Paul's publishing credits include over 200 articles and eight books on the subject of critical thinking (Foundation for Critical Thinking, 2019). He lectured about critical thinking at universities around the world and taught critical thinking courses for over 20 years. Dr. Linda

Elder is an educational psychologist, has published over 100 articles, and has authored and co-authored five books and 24 Thinker's Guides on critical thinking. She has presented her work on critical thinking to over 50,000 educators at all levels (Foundation for Critical Thinking, 2019). The professional development used in this study is designed for teachers of any level teaching any discipline. Teachers were introduced to the definition of critical thinking and its elements. Teachers learned how to incorporate the elements of thought, including analytical reasoning, interpretation, assumptions, inference skills, and overall decision-making skills. Teachers studied and incorporated intellectual standards such as clarity, logic, relevance, and depth and breadth in order to make reliable conclusions and intellectual traits (Foundation for Critical Thinking, 2019). An intended outcome for teachers is the infusion of analytical reasoning skills, inference skills, decision-making skills, and reasoning skills through problems including academic, intellectual, political, personal, and social, and present students with the means to do the same. Teachers also learned to teach and use the strategies to help student participants learn and use critical thinking skills. Each of the professional development programs selected met the treatment protocol of a minimum of 20 hours over the course of one semester focused on critical thinking instruction.

Professional Development Intervention 1. In treatment group TG1, the teachers enrolled in a 15 week, structured asynchronous online professional development course. The course was accessed via the Foundation for Critical Thinking's LMS on their website. The course was structured on a weekly schedule where teachers completed weekly reading assignments, watched videos, participated in discussion sessions, and completing practical application activities, including redesigning existing lessons (Foundation for Critical Thinking, 2019). Instructional redesign was a focus of the course, where teachers took the material and

incorporated the information to redesign their current lessons. Participants in the course were expected to complete a weekly journal entry, submit a weekly instructional redesign paper, and provide feedback on other students' redesign papers and discussion posts. Feedback was given by the instructor of the course and from peers participating in the course in the form of class discussion posts and comments on instructional redesign papers. The course also offered synchronous virtual Socratic discussions. Although there were weekly deadlines for activities, papers, and discussion posts, there was no accountability in the form of a grade for the course. Accountability for course participation and integration of material was tracked in the form of a course survey. Course participants completed a monthly survey indicating how often the professional development materials were accessed and how they were incorporated into their classroom activities. The course started in late August and concluded in early December. The fifteen-week semester-long class is expected to take on average two to four hours per week for each participant, with a minimum of 20 hours per treatment protocol.

Professional Development Intervention 2. In treatment group TG2, the teachers participated in a semester-long asynchronous professional development with a modular design that had no assignments or due dates. The professional development was self-paced, with no facilitator oversight. Videos created by Dr. Richard Paul were uploaded to a Google classroom by the researcher. The professional development included six modules. The first module included an introduction to the course, stating the format and purpose of the course, and background on Dr. Richard Paul.

The following five modules included video-based professional development as well as optional discussion questions and activities. In module one, the video-based professional development focused on how to teach students how to see the logic and how to teach students to

listen, read, and write well while applying critical thinking skills. In module two, teachers also learned to teach and use the strategies to help the student participants learn and use critical thinking skills. In module three, teachers were required to watch videos that covered the foundation of how to teach students to assess their work as well as tactics to do so, and how to teach students to use analytical reasoning, interpretation skills, understand assumptions, inference skills, and overall decision-making skills. In module four, the video-based professional development also included how to design assignments and activities that require and foster the development of critical thinking skills. Teachers learned to include critical thinking into their daily discussions, lessons, assignments, and assessments. There was an optional module created for those teachers who taught mathematics, which included critical thinking and mathematical problem solving skills.

Although there was no accountability with assignments or discussions, teacher participation and incorporation of professional development material was tracked via teacher surveys. The intervention started in late August and concluded in early December. The fifteen-week semester-long class took on average one to two hours per week for each participant, with a minimum of 20 hours per treatment protocol.

Teachers. The teachers were adults over the age of 18, with a teaching credential or equivalent, teaching college preparatory, honors or Advanced Placement courses in high school. Teachers possessed various teaching styles and had varying levels of education and various backgrounds. The teachers were 67% women and 42% men with an average of twelve years of teaching experience. Both inclusion criteria and exclusion criteria were used in teacher participant selection. Inclusion criteria are defined as key features of the target population, including demographic characteristics. Exclusion criteria include features of the teachers who

meet the inclusion criteria, but when presented with additional characteristics could interfere with the success of the study or increase their risk for an unfavorable outcome.

The following inclusion criteria were used to select the teachers:

- Teachers taught college preparatory, honors or Advanced Placement junior or senior classes

The following inclusion criteria were used to ensure teacher engagement in the professional development programs with regards to this study:

- Teachers agreed to participate in a minimum of 20 hours of professional development over one semester
- Teachers agreed to access professional development course materials at least once a week
- Teachers agreed to incorporate critical thinking skills into lectures, quizzes, tests, projects/labs or other assessments weekly
- Teachers agreed to take a monthly survey indicating their participation and incorporation of critical thinking skills in their instructions
- Teachers agreed to refrain from discussing the professional development with their students so as not to unduly to interfere with pretest or posttest student participant data

Instrumentation

The instrument used to measure students' critical thinking skills in this study was the California Critical Thinking Skills Test. The researcher purchased the test licenses from Insight Assessment. This assessment is based on the APA Delphi Consensus Definition of Critical Thinking (Facione, 1990). Although there are many different definitions of critical thinking,

many have overlapping themes and constructs. The APA Delphi Consensus Definition of Critical Thinking is as follows: Critical thinking is purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based (Facione, 1990). The APA Delphi consensus was developed by 46 experts in the field of critical thinking and has been endorsed worldwide by scholars and educators since its inception (Facione, Facione, Blohm & Gittens, 2008; Insight Assessment, 2019). As this definition is not the sole definition of critical thinking, its constructs are comparable to definitions used in the professional development interventions in this study. The assessment is a point of comparable magnitude as the professional development interventions included the aspects of APA Delphi definition throughout the critical thinking training.

The instrument's questions are continually updated by experts in critical thinking to ensure the questions are culturally relevant and current (Insight Assessment, 2019). The intended population for this assessment is college preparatory high school students, undergraduate, and graduate students. The assessment is 40-item multiple choice in format. The items use everyday scenarios, and no specialized knowledge is needed for valid testing as all information needed to respond to the assessment is provided in the test itself (Insight Assessment, 2019). The reading level required for the assessment is a Flesch-Kincaid reading grade level of 8.6 or lower.

The California Critical Thinking Skills Test focuses on eight subsets of critical thinking (a) overall (b) analysis (c) interpretation (d) inference (e) evaluation (f) explanation (g) induction (h) deduction (Insight Assessment, 2019). Analysis includes analytical reasoning skills that enable people to identify assumptions and claims and how they interact to form an argument

(Insight Assessment, 2019). The interpretation subset includes interpretative skills, discovering the context, significance, and meaning of information. Inference skills enable students to draw conclusions from evidence or facts. Evaluation consists of evaluative reasoning skills which are used to assess the credibility of claims and presented information while determining the strength of arguments (Insight Assessment, 2019). Explanation includes explanatory reasoning skills accessed before making a final decision, while induction consists of decision-making skills based on drawing inferences about what an individual thinks is true based on data, patterns, experiences, and behaviors (Insight Assessment, 2019). Deduction is related to induction, yet it includes decision making skills that are based on rules, values, policies, and procedures, and are logical and clear cut (Insight Assessment, 2019). The assessment assigns an overall numerical percentile as well as a category consisting of superior, strong, moderate, weak, or not manifested for all of the subsets. For example, a percentage of 86% or higher in overall critical thinking skills is considered superior, while scores of 69% and lower are considered weak.

Validity and Reliability

The California Critical Thinking Skills Test (CCTST) has a high degree of validity and has established correlations with standardized tests in high school and beyond where higher-order reasoning is demonstrated (Graduate Record Exam (GRE) Total Score: Pearson r = .719, $p<.001$; GRE Analytic r = .708, p<.001; GRE Verbal r = .716, p<.001; GRE Quantitative, r = .582, p<.001; Insight Assessment, 2018). California Critical Thinking Skills Test has a high degree of validity in adult student populations (Agdas, 2013; Behar-Horenstein & Niu, 2011; Facione, Facione & Fiancarlo, 2000; McGuire, 2010; Phelan, 2012; Reid, 2000). A relationship between the CCTST and the GRE total, Analytical, Verbal, and Quantitative sections, and the

SAT Math and Verbal sections have been established with a KR-20 alpha ranging from .70-.75 (Facione, Facione & Fiancarlo, 2000).

The CCTST also has a high degree of validity in high school populations as the CCTST and SAT performance are significantly related in both the verbal and math portions, SAT-V $r = .66$, $p < .01$ and SAT-M $r = .69$, $p < .01$ (Bycio & Allen, 2009). The student scores on the CCTST also predicted overall GPA, $r = .41$, $p < .01$ (Bycio & Allen, 2009). In a high school population, a positive relationship between the Read Theory critical Reading Comprehension Test (RTCRCT) and the California Critical Thinking Skills test was found with a Pearson Product-Moment Correlation Coefficient $r = 0.723$, $p = 0.000 < 0.05$] (Tous et al., 2015). The RTCRCT tests comprehension in terms of critical thinking skills. Students who scored higher on the RTCRCT also scored higher on the CCTST (Tous et al., 2015). Higher performing students scored higher on the CCTST than did lower performing students (Siddiqi et al., 2016). The CCTST accounted for a significant variance (58.7%) in academic performance, $t = 4.54$; $p<.01$ (Siddiqi et al., 2016).

Furthermore, gain in critical thinking skills has been measured using the CCTST in a one-semester time period (Facione et al., 2000). Studies that examined for re-test bias found no testing effect from pretest and posttest means using two independent groups (Behar-Horenstein & Niu, 2011). The Cronbach's Alpha for the CCTST meets or exceeds .70. Test-retest reliability for the assessment meets .80 when retested at two weeks, and many samples demonstrate no change when retested at longer intervals when no training in critical thinking took place (Insight Assessment, 2019). Reliability coefficients range between .77-.83, and subset scores statistics demonstrate similar strengths (Insight Assessment, 2019). In Sorensen & Yankech, 2008, they

evaluated the subscale of critical thinking skills of the experimental group on the California Critical Thinking Skills Test CCTST ($F = 4.709$, $p = .039$).

Quantitative demographic surveys. Participants were asked to complete a demographic survey, which was included at the beginning of the CCTST to define the sample. Surveys provide useful information and have a long history in educational fields as a research tool (Creswell, 2015). For a list of included questions, see Appendix G.

Quantitative professional development intervention survey. Teachers responded to a monthly survey used to assess teacher participation in professional development and teacher incorporation of professional development skills used in instruction. The survey supported and reflected the research questions in this study. The first few questions assessed the teachers' participation in professional development, as outlined in the intervention protocol. The next set of questions assessed the teachers' application and integration of professional development skills into instructions and was closely aligned with study research questions two through five. These questions comprised 5-point Likert scaled items such as 5 -Daily, 4- At least once a week, 3- 2 to 3 times a month, 2-Once a month, 1-Never, to assess the frequency of incorporation of specific critical thinking skills into instruction. Data were analyzed using frequencies and reported as percentages. This second part of the survey was divided into five subsets, which correlated with research questions two through five in this study. The subsets included analytical reasoning skills, inference skills, evaluative reasoning skills, and decision-making skills and covered incorporation of skills in lectures, tests, quizzes, assignments, labs, and projects, see Appendix K.

Data Collection

School consent. Before data collection, superintendents from California, Wisconsin, Minnesota, and Colorado were contacted via email and via phone call about the study. The superintendents and assistant superintendents provided names of principals whose schools met the site criteria of offering a minimum of four high level college preparatory, honors or Advanced Placement classes for junior and senior students. Depending on the district protocol, principals were emailed or called, agreements to participate in the study were established, and IRB approval was gained. Schools contacted were private, public, and had varying demographics and socioeconomic status. From the schools that responded, school demographics, including ethnicity, socioeconomic status, private vs. public, and size, were examined. The number of AP and honors classes offered was also examined. Although attempts were made to find three schools that had similar sizes, ethnicity, socioeconomic status, and were either private or public, no three schools had similar demographics. Although the school ethnic demographics were different, the three groups were similar in their socioeconomic status and educational level. There is a high positive correlation between socioeconomic status and education (Rachmatulla et al., 2019). In a study by Liao et al. (2018), socioeconomic status was used for group similarity, while in a study by Noltemeyer et al. (2010), socioeconomic status was treated as a covariate due to the strong correlation between education and socioeconomic status. Education and socioeconomic status are closely tied (Becker et al., 2019). Three schools were identified in California that met the site criteria, had similar socioeconomic status, and a similar number of offerings of AP and honors classes. After IRB approval, teachers were contacted.

Teacher data collection. After identifying the three schools for the study, teachers were notified via email provided by the principal and school websites, explaining the study. Teacher volunteers were solicited to participate in the study and given the criteria for the study, see Appendix E. Informed consent was gathered from each teacher before the study (See appendix A). From the teacher responses, fourteen teachers volunteered from the three school sites. The teachers were assigned to either an intervention group that participated in a professional development program or assigned to the control group that did not participate in a professional development program, see Table 3.

Table 3

Study Assignment for Teachers

Group	Assignment	Treatment
TG1	Non R	X_1
TG2	Non R	X_2
CG1	Non R	

Note: Table 3 presents the study design for this study. TG = Treatment Group, CG = Control Group, X = Treatment, Non R = Non Random Selection

Site one was assigned to intervention group one, site two was assigned to intervention group two, and site three was assigned to be the control group. Site one had a total of five class sections, site two comprised three class sections, and there were six class sections in site three. The teachers designated to the intervention groups were given the treatment protocol and professional development requirements and agreed to participate in a long-term research project and committed to completing the various professional development programs in the allotted time given by the researcher.

Before the professional development intervention began, one teacher from site one declined to participate in the study citing class load as the reason. After the study began, a second teacher from site one was unable to continue in the study due to health reasons. Two teachers from site three did not complete the study due to not enough time in their schedule to give the posttest to students. Teachers were not notified of other professional development programs available in the study.

A quantitative professional development intervention survey was given to each teacher in August, at the start of the semester before any professional development began and again at the end of each month during the duration of the study. All teachers received a login and directions from the researcher on how to access the survey via Qualtrics. No instructors' names were printed in the results to maintain the confidentiality and privacy of participants.

The survey was taken a total of five times by each of the teachers to ensure the professional development criterion was maintained. This instrument was used by the researcher to assess teacher participation and the use of critical thinking instruction. Each survey took 10-15 minutes to complete, and all precautions were taken to keep the integrity of the survey, which included IT support staff available to help with any computer issues. All data was kept in password-protected files as approved by the Institutional Review Board at Northwest Nazarene University. Within three years, all data from the study will be destroyed (45 CFR 46.117).

Student participant data collection. Extra care must be taken when participants are part of a vulnerable population (Marshall & Rossman, 2015). When designing this study, extra care and diligence were taken. To safeguard participants' privacy and treatment in the research process and beyond, the researcher completed training certified by the National Institute of Health in human research. (see Appendix J). All student participants recruited were high school

juniors and seniors who met the participant study criteria. The first step in student data collection was obtaining parental consent. Informed consent was gathered from participating students' parents/guardians before the study; see appendix B. A physical letter was sent along with the informed consent to parents of students on the first day of classes (see Appendix C). The parental consent forms were distributed to students, along with class syllabi when available. At each school site, parents are required to sign course syllabi for each class. Parental consent forms were distributed along with the syllabi on the first day of school when possible. Three of the control site class sections did not join the study until after the first day of school. In these three cases, the parental consent form was distributed as an individual document that was returned by the students before students took the pretest. The parental consent forms were distributed once, and no further attempts were made to contact. Approximately 389 consent forms were distributed to participants, and 308 consent forms were returned, an initial response rate of 79%.

Assent was obtained by reading the assent script to students (see Appendix D). Student participants were not made aware if they were part of an intervention group or the control group. All participants received a login to access and directions from the researcher. Student participants were assigned individual alphanumeric codes to ensure confidentiality from pretest-posttest results provided by Insight Assessment, the testing agency. No student participants' names were printed in the results to maintain the confidentiality and privacy of participants. No copies were made of any material by the researcher or any other entity. All material related to the study was stored in a password protected computer known only to the researcher. No individual identities were used in any reports or publications that may result from this study. In compliance with the Federal wide Assurance Code, data from this study will be kept for three years, after which all data from the study will be destroyed (45 CRF 46.117).

The California Critical Thinking Skills Test was given to all students twice, once at the start of the semester and again at the end of the semester. Before the test was given, student participant assent was obtained by reading the assent script to each student before participating in the research study, see appendix D. Participants were instructed not to discuss the test to minimize threats to the validity of the posttest scores. The assessments were taken online and provided with permission by Insight Assessment, the provider of the testing instrument. This instrument was used by the researcher to assess, grade tests, and perform statistical analysis. Each test took 45-50 minutes to complete, and all precautions were taken to keep the integrity of the test. The researcher was present during the student testing to ensure testing conditions were adequate and to help with any technical issues with student computers.

Analytical Methods

The individual student participant test scores were reported as a raw overall of critical thinking ability, a categorical interpretation of the strength of the participants' overall score, a percentile ranking compared to other similar test takers, and scale scores including analytical reasoning skills, inference skills, evaluative reasoning skills, and decision-making skills, which indicate which of the skill areas are strong or weaker and require training attention (Insight Assessment, 2018). The score report also included descriptive statistics of the average overall and subscores for the group (Insight Assessment, 2018). Descriptive statistics including the size of the group, mean, median, standard deviation, standard error of the mean, lowest score, highest score, first quartile score, and third quartile score, demographics and the average percentile of the group were obtained from the testing agency (Insight Assessment, 2019).

A paired sample *t* tests and ANCOVA were performed for each research question. The analysis was conducted using SPSS. For the purpose of all statistical tests, a resulting p-value

equal to or less than 0.05 was considered significant. The effect size was calculated for the overall composite scores, and a 95% confidence interval was used. A paired or dependent *t* test was performed to determine if there was a statistically significant difference between two paired observations, where the same individuals were tested at two points in time (Lund Research Ltd, 2019).

Paired *t* test requires that the participants meet specific assumptions. The first assumption is that there is one dependent variable that is measured on a continuous level. The continuous level dependent variable was the California Critical Thinking Skills Test. The second assumption is that there is one categorical or dichotomous independent variable. The dichotomous independent variable is the repeated measure of the California Critical Thinking Skills Test, used first as a pretest and secondly as a post-test. Difference scores and boxplots were examined for the existence of outliers between the pretest scores and posttest scores for each group. The next assumption of normality was examined by using a Shapiro-Wilk test and a Normal Q-Q Plot. After examining the assumptions using the data set, a paired sample *t* test was done for each group.

ANCOVA is used to determine if there are statistically significant differences between the adjusted population means of two or more independent groups on the same interval level dependent variable (Frey, 2016; Lund Research Ltd, 2019). In nonrandomized research designs, "the main purpose of ANCOVA is to adjust the posttest means for differences among groups on the pretest, because such differences are likely to occur with intact groups" (Dimitrov & Rumrill, 2003, p.161). Before the ANCOVA was run, assumptions were addressed. The first assumption was that there is one dependent variable measured on a continuous level. The continuous level dependent variable was the California Critical Thinking Skills Test. The second assumption was

there is one independent variable that consists of two or more independent categorical groups (Lund Research Ltd, 2019). There were three independent groups, treatment group TG1, treatment group TG2, and the control group CG1.

The next assumption was that there is a covariate, which is used to adjust the means of the categorical independent groups. The pretest was the covariate, and the means of the pretests were adjusted better to assess the difference between the three groups' posttest scores. Participants' post-test scores will likely depend on their pretest scores; an ANCOVA is used to compare differences in post-intervention scores between the interventions using the pretest scores as a covariate. Another assumption that needed to be met before performing ANCOVA is there must be independence of observations, meaning that there was no relationship between the participants in each independent group (Lund Research Ltd, 2019). There were three groups, treatment group TG1, treatment group TG2, and the control group CG1 in which each group had unique participants.

The next assumption was verifying the covariate (analytical reasoning skills subset pretest score) is linearly related to the dependent variable (analytical reasoning skills subset posttest score) at each level of the independent variable by visual inspection of a grouped scatterplot of the dependent variable, against the covariate, grouped on the independent variable (Lund Research Ltd, 2019). To meet the assumption of homogeneity of regression slopes, scatterplots were used to examine if there is a statistically significant interaction term between the independent variable and the covariate (Gilner et al., 2003). A Shapiro-Wilk's test, normal Q-Q plots, and histograms were used to determine if residuals were normally distributed; Shapiro-Wilk test is recommended for sample sizes of less than 50; determining normality for larger

sample sizes is best suited by graphical methods, including Normal Q-Q plots and histograms (Lund Research Ltd, 2019).

Homoscedasticity was assessed by visual inspection of the standardized residuals plotted against the predicted values. The existence of outliers was done by examining if there were standardized residuals greater than ±3 standard deviations. The homogeneity of regression assumption was done to evaluate the relationship between the dependent variable, the California Critical Thinking Skills Test post-test scores, and the covariate (student pretest scores). It was done to reduce the possible variance error due to the covariate. Pretests may affect the outcome of the experiment, and to control that potential effect, the covariate needs to be statistically controlled (Mertler, 2016). Covariates are variables that relate to the dependent variable but not the independent variable and can be controlled using statistics (Mertler, 2016). After testing the assumption for homogeneity of regression, an ANCOVA was performed to reduce the error variance to help eliminate systematic bias (Dimitrov & Rumrill, 2003). A pairwise comparison using a Bonferroni post hoc test was done to assess where the differences lie between groups (Field, 2015; Lund Research Ltd, 2019).

There were originally fourteen class sections; the final study included ten class sections. Before the study began, one teacher from treatment group TG1 declined to participate in the study, citing class load as the reason. After the study began, a second teacher from treatment group TG1 was unable to continue due to health reasons. Two teachers from the control group did not complete the study due to not enough time in their schedule to give the posttest to students.

The original sample was 389 students from three sites and fourteen class sections. Approximately 389 consent forms were distributed to participants, and 308 consent forms were

returned; of those 308 participants, 244 took the initial assessment. The initial response rate was 79%, 389 in the population, and 308 returned consent forms. Sixty-four students chose not to take the pretest or were absent the day it was given; 34 students chose not to take the assessment, and 30 students were either absent or had transferred classes and therefore were not included in the study. The overall pretest response rate was 63%; 389 consent forms distributed, and 244 students took the pretest. The pretest was only offered one time at the beginning of the semester; students were not allowed to take it at any other time. The sample for the quantitative analysis began with 244 student participants from thirteen class sections at three different sites. Some participants were excluded for not completing the requirements of the study; 92 students either did not take the post-test (80 students), did not meet minimum time requirements (7 students) or did not answer the minimum number of questions (5 students) required to obtain a valid testing result and were therefore not included in the final study population (Frisby & Traffanstedt, 2003; Insight Assessment, 2019). The final study population consisted of ten class sections and 152 students. The overall rate of participation was 39%; 389 consent forms distributed; 152 students included in the final study data.

A power analysis was completed using the pretest scores of the treatment groups and the control group CG1 California Critical Thinking Skills Test. The control group's overall pretest score average was 72.26%, with a standard deviation of 6.72, and the treatment group's overall pretest scores were 68.45%. Using a one-sided test with a p-value of 0.05, and the desired power of 0.80, the sample size needed for each separate sample was 39.

RQ1: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact critical thinking skills of high school students taking

college preparatory classes as measured by the overall score on the California Critical Thinking Skills Test?

H_a1: There will be a statistically significant difference between total pretest scores and total posttest scores on the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

H_01: There will be no statistically significant difference between total pretest scores and total posttest scores on the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

To test null hypothesis 1, three separate paired sample *t* tests were run for treatment group TG1, treatment group TG2, and the control group CG1 using SPSS to examine if overall critical thinking post-test scores were statistically different from overall pre-test scores for each group. In this case, the continuous dependent variable is the student participant test scores, and each group took the test twice, once as a pretest and once as a post-test.

To test null hypothesis 1, the nominal scale dichotomous independent variable was the professional development intervention. A dichotomous variable is a nominal variable that contains only two categories that do not have an intrinsic order and are mutually exclusive such as intervention and control group (Lund Research Ltd, 2019). The continuous interval scale dependent variable was the participants' overall pretest and overall posttest scores using the testing instrument, the California Critical Thinking Skills Test.

An ANCOVA was done to explore if there were differences between treatment group TG1, treatment group TG2, and the control group CG1. The continuous level dependent variable was the overall post-test score from the participants' California Critical Thinking Skills Test. The covariate was the participants' overall pretest scores. There were three independent groups:

treatment group TG1, treatment group TG2, and the control group CG1. A pairwise comparison using a Bonferroni post hoc test was made to assess where the differences lay between groups (Field, 2015; Lund Research Ltd, 2019).

RQ2: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact analytical reasoning skills of high school students taking college preparatory classes as measured by the analysis subset score on the California Critical Thinking Skills Test?

H_a2: There will be a statistically significant difference between the pretest scores and posttest scores on the analytical reasoning subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

$H_0$2: There will be no statistically significant difference between the pretest scores and the posttest scores on the analytical reasoning subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

To test null hypothesis 2, three separate paired sample *t* tests were run for treatment group TG1, treatment group TG2, and the control group CG1 using SPSS to examine if analytical reasoning skill post-test scores were statistically different from analytical reasoning skill pre-test scores for each group. In this case, the continuous dependent variable was the participants' test scores, and each group took the test twice, once as a pretest and once as a post-test.

Research question 2 was also tested by analyzing an ANCOVA, analyzing if there were differences between the analytical reasoning skill post-test scores in the three groups. The nominal independent variables were professional development one, professional development two, and the control group. The covariate was the participants' analytical reasoning skills pretest scores. The interval scale dependent variable was the analytical reasoning skills posttest subset

score. A pairwise comparison using a Bonferroni post hoc test was done to assess where the differences lay between groups (Field, 2015; Lund Research Ltd, 2019).

RQ3: Does teacher participation in critical thinking professional development impact inference skills of high school students as measured by the inference subset score on the California Critical Thinking Skills Test?

H_a3: There will be a statistically significant difference between the pretest scores and posttest scores on the inference skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

$H_0$3: There will be no statistically significant difference between the pretest scores and the posttest scores on the inference skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

To test null hypothesis 3, three separate paired sample *t* tests were run for treatment group TG1, treatment group TG2 and the control group CG1 using SPSS to examine if inference skill post-test scores were statistically different from inference skill pre-test scores for each group. In this case, the continuous dependent variable is the participants' inference skills subset test scores, and each group took the test twice, once as a pretest and once as a post-test.

Research question 3 was also tested by analyzing an ANCOVA, analyzing if there were differences between the inference skill post-test scores in the three groups. The nominal independent variables were professional development one, professional development two, and the control group. The covariate was the participants' inference skill pretest scores. The interval scale dependent variable was the inference skill posttest subset score. A pairwise comparison using a Bonferroni post hoc test was done to assess where the differences lay between groups (Field, 2015; Lund Research Ltd, 2019).

RQ4: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact evaluative reasoning skills of high school students as measured by the evaluation subset score on the California Critical Thinking Skills Test?

H_a4: There will be a statistically significant difference between the pretest scores and posttest scores on the evaluative reasoning skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

$H_0$4: There will be no statistically significant difference between the pretest scores and the posttest scores on the evaluative reasoning skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

To test null hypothesis 4, three separate paired sample *t* tests were run for treatment group TG1, treatment group TG2, and the control group CG1 using SPSS to examine if evaluative reasoning skill post-test scores were statistically different from evaluative reasoning skill pre-test scores for each group. In this case, the continuous dependent variable is the participants' evaluative reasoning skill subset test scores, and each group took the test twice, once as a pretest and once as a post-test.

Research question 3 was also tested by analyzing an ANCOVA, analyzing if there were differences between the evaluative reasoning skill post-test scores in the three groups. The nominal independent variables were professional development one, professional development two, and the control group. The covariate was the participants' evaluative reasoning skill pretest scores. The interval scale dependent variable was the evaluative reasoning skill posttest subset

score. A pairwise comparison using a Bonferroni post hoc test was done to assess where the differences lay between groups (Field, 2015; Lund Research Ltd, 2019).

RQ5: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact decision-making skills of high school students as measured by the induction and deduction subset scores on the California Critical Thinking Skills Test?

H_a5: There will be a statistically significant difference between the pretest scores and posttest scores on the decision-making skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

$H_0$5: There will be no statistically significant difference between the pretest scores and the posttest scores on the decision-making skills subscale of the California Critical Thinking Skills Test after teachers participate in professional development focused on critical thinking skills.

To test null hypothesis 5, six separate paired sample *t* tests were run for treatment group TG1, treatment group TG2 and the control group CG1 using SPSS to examine if inductive decision-making skills and deductive decision-making skill post-test scores were statistically different from inductive decision-making skills and deductive decision-making skill pre-test scores for each group. In this case, the continuous dependent variable is the participants' inductive decision-making skills and deductive decision-making skill subset test scores, and each group took the test twice, once as a pretest and once as a post-test.

Research question 5 was also tested by analyzing an ANCOVA, analyzing if there were differences between the inductive decision-making skills and deductive decision-making skill post-test scores in the three groups. The nominal independent variables were professional development one, professional development two, and the control group. The covariate was the

participants' inductive decision-making skills and deductive decision-making skill pretest scores. The interval scale dependent variable was the inductive decision-making skills and deductive decision-making skill posttest subset scores. A pairwise comparison using a Bonferroni post hoc test was done to assess where the differences lay between groups (Field, 2015; Lund Research Ltd, 2019).

Limitations

Limitations of pretest-posttest research designs include selection, history, maturation, pretest sensitivity, regression, and interaction of these variables (Creswell, 2015; Dimitrov & Rumrill, 2003). Threats to external validity include problems that threaten the ability to draw inferences from the sample to other people or settings (Creswell, 2015). A limitation of this study may emerge since the sample was taken at only three sites, and the narrow demographics may not be representative of all schools. This study did not control many external differences like ethnicity, school location, and gender. Therefore, the results of this study may not be generalized to all high schools.

External validity could not be assured due to the small sample size and setting. Convenience sampling reduces the generalizability of the results. A disadvantage to this type of sampling is that there are less data gathered than when a larger random sample is selected. Therefore it may be more challenging to make a general conclusion about typical instances (Maxwell, 2015).

ANCOVA was used to assess any difference between groups. Participants were in intact groups, which means they were not randomly assigned to their respective groups. Caution should be taken when interpreting the results from ANCOVA if groups are not randomly assigned (Gliner et al., 2003). Using an ANCOVA with intact groups can have internal validity issues in

that if differences are found between groups, the differences may be due to the individual characteristics of the intact groups (Dimitrov & Rumrill, 2003). When using intact groups, a limitation exists where intact groups could exhibit differential growth on the dependent variable, the post-test scores (Dimitrov & Rumrill, 2003).

Teachers were self-selected for this study, which further confines the diversity of the participants. The researcher's conclusions and interpretations are limited due to the restricted population. Students also self-selected for the study, which further limits the population, which affects external validity. The class sections were honors and Advanced Placement students, which is a small cluster of each school. This clustering effect impacts external validity.

When interventions are part of research designs, the nature of the intervention can change the teaching in some manner which is not necessarily due to the manipulation of the independent variable and make it difficult to conclude causality between the dependent and independent variable (Cohen et al., 2011, Kirkwood & Price, 2013). There was no standardization of how information from the professional development was applied or integrated into the classroom. Due to the nature of teaching, not all classes are taught in the same manner, and not all teachers incorporated the material from the professional development in the same manner. Teachers vary in their applications and approaches in the classroom, and this possibility of variety is, therefore, a limitation (Kirkwood & Price, 2013).

A threat to external validity is the possibility of a crossover with another teacher professional development during the course of the research. Another limitation of the study is the self-reporting of the participation of the teachers in the professional development interventions. Self-reporting surveys' reliability is dependent on that of the respondents (Queirós et al., 2017).

There is a possibility for researcher bias via participant selection, although much effort was made to eliminate any researcher bias. Pretests can also increase the participants' expectations about the outcome and may influence the experimental treatment or affect posttest scores because participants anticipate the posttest questions based on their involvement with the pretest (Creswell, 2015).

Chapter IV

Results

Introduction

This chapter provides participant sample demographics, reviews research results, and presents the findings of the data obtained from the study. The purpose of this research was to determine if widely accessible, content-focused professional development had the ability to increase students' critical thinking skills. Quantitative statistical analyses were implemented to assess if there were differences between pretest and post-test scores of students' California Critical Thinking Skills Test. Participants were divided into three groups, treatment group TG1 and treatment group TG2 whose teachers received professional development and one control group CG1 where the teachers did not participate in professional development (See Table 4).

Table 4

Study Design (n=152)

Group	Assignment	Pretest	Treatment	Posttest
TG1 (*n*=58)	Non R	O_1	X_1	O_2
TG2 (*n*=52)	Non R	O_3	X_2	O_4
CG1 (*n*=42)	Non R	O_5		O_6

Note: Table 4 presents the study design for this study. TG = Treatment Group, O = Measures, CG = Control Group, X = Treatment,

Non R = Non Random Assignment

All students from each group took the pretest at the beginning of the semester and the posttest at the end of the semester. Statistics were performed comparing the mean pretest scores for control and intervention groups to the mean posttest scores for the control and intervention

groups. An ANCOVA was performed exploring the difference in pretest and posttest scores between groups. For each treatment group, a paired *t* test was run on the overall CCTST scores comparing the mean pretest scores and mean posttest scores. For each group, the effect size was calculated for the overall composite scores. A 95% confidence interval was used for all statistics. Normality tests of the individual group samples, as well as homogeneity of variance, were done to see if the three treatment groups were significantly different. The dependent variable in this study was the student participant CCTST test scores. In addition, quantitative research methodologies were implemented to assess the differences between the groups. Multiple ANCOVAs were used to examine the research questions guiding this study: Research Question One "Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact critical thinking skills of high school students taking college preparatory classes as measured by the overall score on the California Critical Thinking Skills Test?"; Research Question Two "Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact analytical reasoning skills of high school students taking college preparatory classes as measured by the analysis subset score on the California Critical Thinking Skills Test?"; Research Question Three "Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact inference skills of high school students as measured by the inference subset score on the California Critical Thinking Skills Test?"; Research Question Four "Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact evaluative reasoning skills of high school students as measured by the evaluation subset score on the California Critical Thinking Skills Test?"; Research Question Five "Does teacher participation in professional development focused on how to infuse critical thinking into teaching

impact decision-making skills of high school students as measured by the induction and deduction subset scores on the California Critical Thinking Skills Test?"

Sample Demographics

The population for this study was upper-level students enrolled in three high schools in the western United States. Individuals were identified from previously formed college preparatory, honors or Advanced Placement junior and senior-level classes based on teacher participation. The teachers were selected using convenience sampling as they were willing and able to be studied, and they met participant inclusion criteria. Consent was obtained from all eligible individuals, and data was kept confidential. Informed consent was gathered from participating students' parent/guardian prior to the study (see appendix B).

A physical letter was sent along with the informed consent to parents of students on the first day of classes (see Appendix C). The parental consent forms were distributed once, and no further attempts were made to contact. Assent was obtained by reading the assent script to students before the pretest and again before the posttest (see Appendix D). Student participants were assigned an alphanumeric code to ensure confidentiality, and no student participants' names were printed in the results to maintain the confidentiality and privacy of participants. Student participants were not made aware if they were part of an intervention group or the control group to minimize interactions that could potentially influence post-test scores; treatment groups and control groups were separated via different site locations.

The sample for the quantitative analysis began with 244 student participants from fourteen class sections at three different sites. Some participants were excluded for not completing the requirements of the study; 92 students either did not take the post-test (80), did not meet minimum time requirements (7) or did not answer the minimum number of questions

(5) required to obtain a valid testing result and were therefore not included in the final study population (Frisby & Traffanstedt, 2003; Insight Assessment, 2019). The final study population consisted of ten class sections and 152 students.

Table 6 provides demographic information for the study sample. The population contained 74 (48.7%) female, 76 (50%) male and 2 (1.3%) declined to state. The ages of the participants ranged from 16-19 years, consisting of 95 (62.5%) junior-level students and 57 (37.5%) senior-level students. The population contained 69 (45.4%) with a GPA above 4.0, 52 (34.5%) with a GPA between 3.5-3.9, 23 (15.1%) with a GPA between 2.5-2.99, 7, (4.6%) with a GPA between 2.1-2.49, and one student (0.7%) with a GPA under 2.0. The majority of participants reported White Caucasian, Anglo American (N = 66, 54.6%), followed by Asian, Asian American, Pacific Islander (N = 45, 29.6%), Hispanic, Latino, Mexican American (N = 18, 11.8%), Black, African American (N = 6, 3.9%), American Indian/Native American (N = 1, 0.7%), Other (N = 6, 3.9%) and participants that chose not to provide this information (N = 10, 6.6%).

Table 5

Sample Demographics

Variable	*N*	%
Gender		
Female	74	48.7
Male	76	50.0
Declined to state	2	1.3
Age		
16	83	54.6
17	54	35.5
18	14	9.2

19	1	.7
Race/Ethnicity		
White, Caucasian, Anglo American	66	43.4
Asian, Asian American, Pacific Islander	45	29.6
American Indian/Native American	1	.7
Hispanic, Latino, Mexican American	18	11.8
Black, African American	6	3.9
Other	6	3.9
Chose not to provide this information	10	6.6
GPA		
under 2.0	1	.7
2.1-2.49	7	4.6
2.5-2.99	23	15.1
3.5-4.0	52	34.2
above 4.0	69	45.4
Grade Level		
Junior	95	62.5
Senior	57	37.5

Note. Table 5 presents the general demographic data for the participants in the sample. Both the number of respondents and the percentages are provided.

Statistical Findings

In this section, the statistical findings based on the five research questions in this study are presented in detail as well as paired *t* tests for each treatment group to examine if the posttest test scores were significantly different from pretest scores. ANCOVAs for the overall posttest

scores, with adjustment for the covariate, pretest scores were run to examine if there were any differences between groups.

Research Question 1: Overall Critical Thinking Skills

Research question one was to determine if there was a statistically significant difference in students' overall critical thinking in treatment group TG1, treatment group TG2, as compared to the control group CG1. Specifically, this question asked, “Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact critical thinking skills of high school students taking college preparatory classes as measured by the overall score on the California Critical Thinking Skills Test?” The instrument used to determine the statistical difference was the California Critical Thinking Skills Test.

The descriptive statistics for treatment group TG1, treatment group TG2 and control group CG1, were taken from the overall pretest and post-test data from the California Critical Thinking Skills Test and are found in Table 6 and 7. In Table 6 the descriptive statistics for treatment group 1 pretest scores (N = 58, M = 69.9, SD = 8.11) treatment group 2 pretest scores (N = 52, M= 66.85, SD = 5.75) and control group CG1 pretest scores (N= 42, M = 72.26, SD = 6.72). Pretest scores for all three groups were in the weak to moderate range for overall critical thinking skills — weak being between 63-69 and moderate being between 70-78 (Insight Assessment, 2019).

Table 6

Overall Pretest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Range Min	Range Max
TG1	58	69.90	8.11	54	87
TG2	52	66.85	5.75	57	83
CG1	42	72.26	6.72	61	86

Note. Table 6 presents the descriptive statistics mean, standard deviation, range minimum, and range maximum for the pretest scores for treatment group TG1, treatment group TG2, and control group CG1.

In Table 7 the descriptive statistics for treatment group TG1 posttest scores ($N = 58$, M = 74.48, SD = 7.41) Treatment group TG2 posttest scores ($N = 52$, M=69.71, SD= 6.32) and CG1 posttest scores ($N = 42$, M = 73.31, SD = 7.92) are shown. Posttest scores for all three groups were in the moderate range for overall critical thinking skills.

Table 7 *Overall Posttest Descriptive Statistics*

Group	*N*	Mean	Standard Deviation	Range Min	Range Max
TG1	58	74.48	7.413	59	90
TG2	52	69.71	6.322	61	85
CG1	42	73.31	7.922	58	92

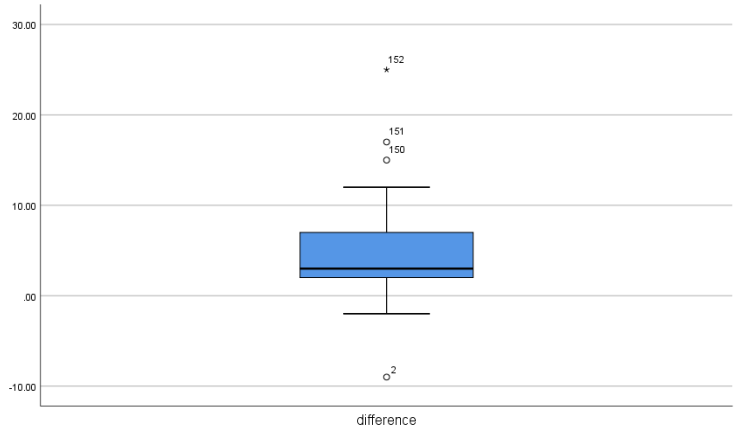
Note. Table 7 presents the descriptive statistics mean, standard deviation, range minimum, and range maximum for the posttest scores for treatment group TG1, treatment group TG2, and control group CG1.

Paired-samples *t* tests examining the overall pretest scores and posttest scores for each group were completed. A Normal Q-Q plot was used to test the assumption of normality. The

difference between overall posttest and pretest for treatment group TG1, treatment group TG2, and control group CG1 was normally distributed as assessed by visual inspection of a Normal Q-Q plot and by visual inspection of their histograms. There were four outliers identified and are found in Figure 4.

Figure 4

Outliers from Overall Difference Scores of Posttest-Pretest



Note. Figure 4 shows the outliers using difference scores, posttest minus pretest from the data set.

To explore the outliers, the data was reviewed for any data entry errors, measurement errors, and to explore if they are genuinely unusual values (Lund Research Ltd, 2019). No errors in data or measurements were found, and so they were determined to be genuinely unique values. One outlier was greater than three standard deviations and needed further examination. To explore the extreme outlier, a dependent *t* test was run with the outlier and without the outlier to see how it may affect the results. The results from treatment group TG1 without the extreme outlier included was a statistically significant increase in overall post-test scores compared to pretest scores, M_{diff} = 4.228, 95% CI [3.052, 5.404], *t*(56), *p*<.001, d = .89. The result of the dependent *t* test with the outlier was M_{diff}= 4.586, 95% CI [3.227, 5.946] *t*(57), *p*<.001, d = .95. Since the removal of the extreme outlier did not affect the result of the

statistical significance, the outlier was left in the data set. Treatment group TG2 did not have any notable outliers, and control group CG1 had one outlier but was not extreme, so it was kept in the analysis.

Overall results rejected the null hypothesis in favor of the alternative hypothesis, as there was a statistically significant difference from overall pretest scores to posttest scores in some groups. As shown in Table 8, treatment group TG1 had a statistically significant increase in overall post-test scores compared to pretest scores, M_{diff} = 4.586, 95% CI [3.227, 5.946] $t(57)$, $p<.001$, d = .95. For treatment group TG2, there was a statistically significant increase in overall post-test scores compared to pretest scores, M_{diff} = 2.865, 95% CI [1.811, 3.920], $t(51)$, $p<.001$, d =.75. For the control group CG1, there was not a statistically significant increase in overall post-test scores compared to pretest scores, M_{diff} = 1.048, 95% CI [-.800, 2.896], $t(41)$, $p = .259$, d = .18.

Table 8

Overall Pretest-Posttest Paired Differences t Test Statistics

Group	Mean Difference	sd	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	sig. (2-tailed)
TG1(*n*=58)	4.586	5.171	.679	3.227	5.946	6.755	57	.000
TG2 (*n*=52)	2.865	3.789	.525	1.811	3.920	5.454	51	.000
CG1(*n*=42)	1.048	5.930	.915	-.800	2.896	1.145	41	.259

Note. Table 8 presents the paired difference statistics for the overall critical thinking scores, including mean difference, standard deviation, standard error, and upper and lower 95% Confidence Intervals for treatment group TG1, treatment group TG2, and control group CG1 using $\alpha < .05$.

An ANCOVA was run to determine if overall posttest critical thinking skills were statistically different from pretest overall critical thinking skills between the three groups, including the control group CG1, treatment group TG1 and treatment group TG2. There was a linear relationship between the overall pretest and posttest for each group, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(2, 146) = 0.812$, $p = .446$. There were two outliers in the data, with standardized residuals greater than ±3 standard deviations. A one-way ANCOVA with and without the outliers included in the analysis was done and both conclusions resulted in a statistically significant result; therefore, the outlier was left in the data set. There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values. Standardized residuals for the interventions were normally distributed for all groups, as assessed by Shapiro-Wilk's test ($p > .05$) for CG1 and assessed by visual inspection of Normal Q-Q Plots for treatment group TG1 and treatment group TG2. Shapiro-Wilk test is recommended for sample sizes of less than 50; determining normality for larger sample sizes is best suited by graphical methods, including Normal Q-Q plots and histograms (Lund Research Ltd, 2019).

After adjustment for pretest scores, the ANCOVA found that there were statistical differences between groups' overall critical thinking skills as measured by the overall pretest-posttest scores from the California Critical Thinking Skills Test, $F(2,148) = 5.877$, $p = 0.03$, partial $n^2 = 0.074$. Post hoc analysis was performed with a Bonferroni adjustment. Table 9 shows the pairwise comparison for the groups.

Table 9

ANCOVA Estimates of Intervention and Control Results for Overall Critical Thinking Scores with Pretest as a Covariate

Group	Mean	Std. Error	95% CI Lower	95% CI Upper
TG1(*N*=58)	74.180[a]	.624	72.947	75.412
TG2(*N*=52)	71.780[a]	.675	70.446	73.114
CG1(*N*=42)	71.167[a]	.749	69.688	72.647

Note. Table 9 presents the ANCOVA estimates for overall critical thinking scores statistics, including mean difference, standard error, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

a. Covariates appearing in the model are evaluated at the following values: Pre OVERALL = 69.51.

Table 10

Pairwise Comparison of Intervention and Control ANCOVA Results for Overall Critical Thinking Scores with Pretest as a Covariate

Group	Group	Mean difference	Std. Error	Sig	95% CI Lower	95% CI Upper
TG1(*N*=58)	TG2 (*N*=52)	2.400	.923	.031	.166	4.634
TG2(*N*=52)	CG1(*N*=42)	.613	1.030	1.000	-1.882	3.107
TG1(*N*=58)	CG1(*N*=42)	3.012	.971	.007	.661	5.364

Note. Table 10 presents the overall critical thinking scores ANCOVA statistics, including mean difference, standard error, significance, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

Treatment group TG1 (M = 74.18) is statistically significantly different than control group CG1 (M = 71.17), a mean difference of 3.012, 95% CI [.661, .364], p =.007. After adjustment for the pretest, there was also a statistically significant difference in overall critical thinking post-test between treatment group TG1 and treatment group TG2. Treatment group TG1 (M = 74.18) is statistically significantly different from treatment group TG2 (M = 71.17) with a mean difference of 2.400, 95% CI [0.166, 4.634], p = 0.031. There were no other significant differences among groups.

Research Question 2: Analytical Reasoning Skills

Research question two was to determine if there was a statistically significant difference in students' analytical reasoning skills in participants in treatment group TG1, treatment group TG2, as compared to the control group, CG1. Specifically, this question asked, “Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact analytical reasoning skills of high school students taking college preparatory classes as measured by the analysis subset score on the California Critical Thinking Skills Test?” The instrument used to determine the statistical difference was the California Critical Thinking Skills Test.

Table 11 and Table 12 show the analysis subset pretest and posttest descriptive statistics for treatment group TG1, treatment group TG2, and control group CG1. In Table 11 the descriptive statistics for treatment group TG1 pretest scores (N = 58, M = 69.57, SD = 9.059) treatment group TG2 pretest scores (N = 52, M = 66.37, SD = 6.457) and control group CG1 pretest scores (N = 42, M = 72.43, SD = 8.344). Pretest scores for all three groups were in the weak to moderate range for the analysis subset — weak being between 63-69 and moderate being between 70-78 (Insight Assessment, 2019).

Table 11

Analysis Pretest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	69.57	9.059	1.190
TG2	52	66.37	6.457	.895
CG1	42	72.43	8.344	1.287

Note. Table 11 presents the analysis scores descriptive statistics including mean, standard deviation, standard error mean for the analytical reasoning pretest scores for treatment group TG1, treatment group TG2, and control group CG1.

In Table 12 the analysis subset descriptive statistics for treatment group TG1 posttest scores ($N = 58$, M = 74.62, SD = 8.788) TG2 posttest scores ($N = 52$, M = 70.06, SD = 8.233) and control group CG1 posttest scores ($N = 42$, M = 72.38, SD = 11.032). Analysis posttest scores for all three groups were in the moderate range.

Table 12

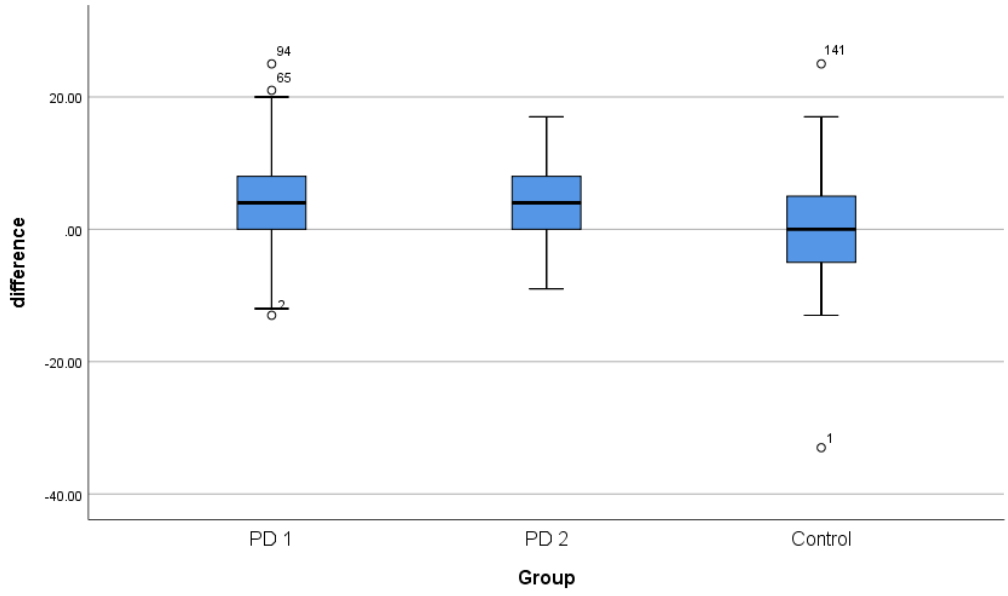
Analysis Posttest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	74.62	8.788	1.154
TG2	52	70.06	8.233	1.142
CG1	42	72.38	11.032	1.702

Note. Table12 presents the analysis scores descriptive statistics including mean, standard deviation, standard error mean for the analytical reasoning posttest scores for treatment group TG1, treatment group TG2, and control group CG1.

A paired sample *t* test was completed to asses if there were any differences among the group's posttest and pretest scores. A Normal Q-Q plot was used to test the assumption of normality. The difference between analysis posttest and pretest for treatment group TG1, treatment group TG2, and control group CG1 were normally distributed as assessed by visual inspection of a Normal Q-Q plot and by visual inspection of their histograms. Five outliers were detected that were more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of their values did not reveal them to be extreme, and they were kept in the analysis, as shown in Figure 5.

Figure 5 *Outliers from Analysis difference Scores of Posttest-Pretest*



Note. Figure 5 shows the outliers using difference scores, posttest minus pretest from the analysis subset data.

In Table 13, the results of paired-samples *t* tests examining the analysis of pretest scores and posttest scores for each group are found. Treatment group TG1 had a statistically significant increase in analysis subset post-test scores compared to analysis subset pretest scores, M_{diff} = 5.052, 95% CI [3.124, 6.979], $t(57) = 5.248$, $p<.001$, d = .68. For treatment group TG2, there

was a statistically significant increase in analysis post-test scores compared to pretest scores, M_{diff} = 3.692, 95% CI [2.236, 5.122], $t(51)$, $p<.001$, d = .72. For the control group CG1, there was not a statistically significant increase in analysis post-test scores compared to pretest scores, M_{diff} = -0.048, 95% CI [-3.218, 3.123], $t(41)$, $p = 0.976$.

Table 13

Analysis Pretest-Posttest Paired t Test Statistics

Group	Mean difference	sd	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	sig. (2-tailed)
TG1(*n*=58)	5.052	7.330	.963	3.124	6.979	5.248	57	.000
TG2 (*n*=52)	3.692	5.136	.712	2.263	5.122	5.185	51	.000
CG1(*n*=42)	-.048	10.174	1.570	-3.218	3.123	-.030	41	.976

Note. Table 13 presents the paired difference statistics for the analysis subset scores, including mean difference, standard deviation, standard error, and upper and lower 95% Confidence Intervals for treatment group TG1, treatment group TG2, and control group CG1 using $\alpha < .05$.

An ANCOVA was run to determine if analytical reasoning post-test scores were statistically different from pretest analytical reasoning skills between the three groups, including the control group and the two treatment groups. There was a linear relationship between analytical reasoning skills pretest and posttest for each group, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(2, 146) = 2.03$, p = .135. There was one outlier in the data, as with standardized residual greater than ±3 standard deviations. A one-way ANCOVA with and without the outlier included in the analysis was done and both conclusions resulted in a statistically significant result; therefore, the outlier was left in the data set. There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against

the predicted values. Standardized residuals for the interventions were normally distributed for all groups, as assessed by Shapiro-Wilk's test ($p > .05$) for control group CG1 and assessed by visual inspection of Normal Q-Q Plots for treatment group TG1 and treatment group TG2. Shapiro-Wilk test is recommended for sample sizes of less than 50; determining normality for larger sample sizes is best suited by graphical methods, including Normal Q-Q plots and histograms (Lund Research Ltd, 2019).

Advanced level high school students with teachers enrolled in PD1 (a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) showed a statistically significant increase from a control group in analytical reasoning skills as measured by the California Critical Thinking Skills Test (CCTST). $F(2,148) = 4.234$, $p = 0.016$, partial $n^2 = 0.054$. Post hoc analysis was performed with a Bonferroni adjustment, and Table 14 and Table 15 shows the pairwise comparison for the groups. Treatment group TG1 (M = 74.40, SD = 7.41) is statistically significantly different from the control group CG1 (M = 70.11, SD = 7.92), a mean difference of 4.291, 95% CI [0.674, 7.907], $p = 0.014$ as shown in Table 16. There were no other significant differences among groups.

Table 14

ANCOVA Estimates of Intervention and Control Results for Analysis Scores with Pretest as a Covariate

Group	Mean	Std. Error	95% CI Lower	95% CI Upper
TG1(*N*=58)	74.401[a]	.958	72.508	76.295
TG2(*N*=52)	72.136[a]	1.034	70.092	74.180
CG1(*N*=42)	70.111[a]	1.150	67.838	72.383

Note. Table 14 presents the ANCOVA estimates for analysis scores statistics, including mean, standard error, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

a. Covariates appearing in the model are evaluated at the following values: Pre Analysis = 69.26.

Table 15

Pairwise Comparison of Intervention and Control ANCOVA results for Analysis Scores with Pretest as a Covariate

Group	Group	Mean difference	Std. Error	Sig	95% CI Lower	95% CI Upper
TG1(*N*=58)	TG2 (*N*=52)	2.265	1.414	.334	-1.158	5.688
TG2(*N*=52)	CG1(*N*=42)	2.026	1.579	.605	-1.799	5.850
TG1(*N*=58)	CG1(*N*=42)	4.291	1.494	.014	.674	7.907

Note. Table 15 presents the ANCOVA statistics, including mean difference, standard error, significance, and 95% Confidence Interval for lower and upper bounds for the analysis subset scores for treatment group TG1, treatment group TG2, and control group CG1.

Research Question 3: Inference Skills

Research question three was to determine if there was a statistically significant difference in students' inference skills in participants in treatment group TG1, treatment group TG2, as compared to the control group CG1. Specifically, this question asked, “Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact inference skills of high school students as measured by the inference subset score on the California Critical Thinking Skills Test?”

Table 16 and Table 17 show the inference subset pretest and posttest descriptive statistics for treatment group TG1, treatment group TG2, and control group CG1. In Table 17 the descriptive statistics for treatment group TG1 pretest scores (N = 58, M = 70.16, SD = 8.267) treatment group TG2 pretest scores (N = 52, M = 66.88, SD = 5.999) and control group CG1 pretest scores (N = 42, M = 72.79, SD = 7.653). Inference pretest scores for all three groups were in the weak to moderate range for overall critical thinking skills — weak being between 63-69 and moderate being between 70-78 (Insight Assessment, 2019).

Table 16

Inference Skills Pretest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	70.16	8.267	1.086
TG2	52	66.88	5.999	.832
CG1	42	72.79	7.653	1.181

Note. Table 16 presents the inference skills descriptive statistics mean, standard deviation and standard error for the pretest scores for treatment group TG1, treatment group TG2, and control group CG1.

In Table 17 the inference subset descriptive statistics for treatment group TG1 posttest scores (N = 58, M = 75.59, SD = 7.956) treatment group TG2 posttest scores (N = 52, M = 71.79, SD = 7.135) and control group CG1 posttest scores (N = 42, M = 73.00, SD = 8.790). Inference posttest scores for all three groups were in the moderate range.

Table 17

Inference Skills Posttest Descriptive Statistics

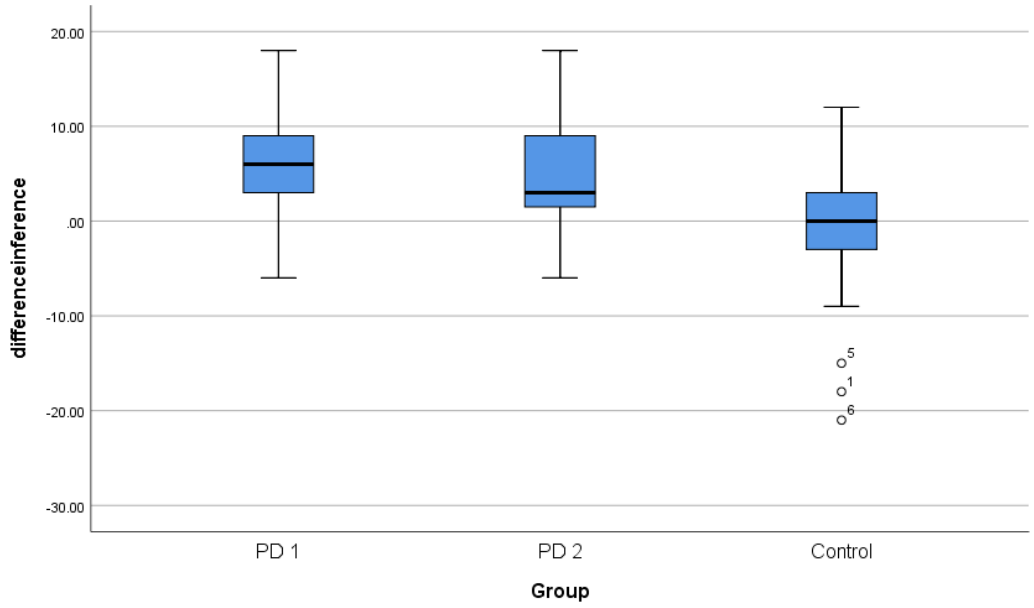
Group	N	Mean	Standard Deviation	Std. Error Mean
TG1	58	75.59	7.956	1.045
TG2	52	71.79	7.135	.990
CG1	42	73.00	8.790	1.356

Note. Table 17 presents the inference skills descriptive statistics mean, standard deviation and standard error for the posttest scores for treatment group TG1, treatment group TG2, and control group CG1.

A paired sample *t* test was run to assess if there were any differences in inference pretest and posttest scores within each group. A Normal Q-Q plot was used to test the assumption of normality. The difference between inference posttest and pretest for treatment group TG1, treatment group TG2, and control group CG1 were normally distributed as assessed by visual inspection of a Normal Q-Q plot and by visual inspection of their histograms. Three outliers were detected that were more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of their values did not reveal them to be extreme, and they were kept in the analysis, as shown in Figure 6.

Figure 6

Outliers from Inference Difference Scores of Posttest-Pretest



Note. Figure 6 shows the outliers using difference inference scores, posttest minus pretest from the inferences scores data set.

In Table 18, the results of paired samples *t* tests examining the inference pretest scores and posttest scores for each group are found**.** Treatment group TG1 had a statistically significant increase in inference post-test scores compared to pretest scores, M_{diff} = 5.430, 95% CI [3.850, 6.429], $t(57) = 6.455$, $p<.001$, d = 0.9. For treatment group TG2, there was a statistically significant increase in inference post-test scores compared to pretest scores, M_{diff} = 4.904, 95% CI [3.379, 5.122], $t(51)$, $p<.001$, d = .89. For the control group CG1, there was not a statistically significant increase in inference post-test scores compared to pretest scores, M_{diff} =.214, 95% CI [-2.098, 2.526], $t(41)$, $p = 0.852$.

Table 18

Inference Pretest-Posttest Paired t Test Statistics

Group	Mean difference	sd	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	sig. (2-tailed)
TG1(*n*=58)	5.431	6.012	.789	3.850	7.012	6.880	57	.000
TG2 (*n*=52)	4.904	5.478	.760	3.379	6.429	6.455	51	.000
CG1(*n*=42)	.214	7.420	1.145	-2.098	2.526	.187	41	.852

Note. Table 18 presents the paired inference skills difference statistics, including mean difference, standard deviation, standard error, and upper and lower 95% Confidence Intervals for treatment group TG1, treatment group TG2, and control group CG1 using $\alpha < .05$.

An ANCOVA was run to determine if inference post-test scores were statistically different from pretest inference scores between the three groups, including in the control group and two treatment groups. There was a linear relationship between inference skills pre- and posttest scores for each group, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(2, 146) = 0.183$, $p = .833$. There were no outliers in the data, as with standardized residual greater than ±3 standard deviations. There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values. Standardized residuals for the interventions were normally distributed for all groups, as assessed by Shapiro-Wilk's test ($p > .05$) for CG1 and assessed by visual inspection of Normal Q-Q Plots for treatment group TG1 and treatment group TG2. Shapiro-Wilk test is recommended for sample sizes of less than 50; determining normality for larger sample sizes is best suited by graphical methods, including Normal Q-Q plots and histograms (Lund Research Ltd, 2019).

Table 19

ANCOVA Estimates of Intervention and Control Results for Inference Scores with Pretest as a Covariate

Group	Mean	Std. Error	95% CI Lower	95% CI Upper
TG1(*N*=58)	75.305[a]	.778	73.767	76.843
TG2(*N*=52)	73.852[a]	.843	72.186	75.518
CG1(*N*=42)	70.834[a]	.936	68.985	72.682

Note. Table 19 presents the ANCOVA estimates for inference scores statistics, including mean, standard error, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

a. Covariates appearing in the model are evaluated at the following values: Pre Inference = 69.76

Table 20

Pairwise Comparison of Intervention and Control ANCOVA Results for Inference Scores with Pretest as a Covariate

Group	Group	Mean difference	Std. Error	Sig	95% CI Lower	95% CI Upper
TG1(*N*=58)	TG2 (*N*=52)	1.454	1.152	.627	-1.335	4.243
TG2(*N*=52)	CG1(*N*=42)	3.018	1.289	.062	-.103	6.139
TG1(*N*=58)	CG1(*N*=42)	4.472	1.213	.001	1.535	7.408

Note. Table 20 presents the ANCOVA inference scores statistics, including mean difference, standard error, significance, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

After adjustment for pretest scores, the ANCOVA found that there was a statistically significant difference in inference post-test scores between treatment group TG1 and the control group CG1. Advanced level high school students with teachers enrolled in PD1 (a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) showed a statistically significant increase from a control group in inference skills as measured by the California Critical Thinking Skills Test $F(2,148) = 6.831$, $p = 0.001$, partial $n^2 = 0.085$. Post hoc analysis was performed with a Bonferroni adjustment, and Table 21 shows the pairwise comparison for the groups. Treatment group TG1 (M = 75.31) is statistically significantly different from the control group CG1 (M = 70.83), with a mean difference of 4.472, 95% CI [1.535, 7.408], $p = .001$, as shown in Table 20. There were no other significant differences among groups.

Research Question 4: Evaluative Reasoning Skills

Research question four was to determine if there was a statistically significant difference in students' evaluative reasoning skills in participants in treatment group TG1, treatment group TG2, as compared to the control group CG1. Specifically, this question asked, “Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact evaluative reasoning skills of high school students as measured by the evaluation subset score on the California Critical Thinking Skills Test?”

Table 21 and Table 22 show the evaluative reasoning skills subset pretest and posttest descriptive statistics for treatment group TG1, treatment group TG2, and control group CG1. In Table 22 the evaluative reasoning skills descriptive statistics for treatment group TG1 pretest scores ($N = 58$, M = 69.57, SD = 7.923) treatment group TG2 pretest scores ($N = 52$, M = 67.85, SD = 6.858) and treatment group TG1 pretest scores ($N = 42$, M = 70.67, SD = 6.203).

Evaluation subset pretest scores for all three groups were on the border of weak to moderate - weak being between 63-69 and moderate being between 70-78 (Insight Assessment, 2019).

Table 21

Evaluative Reasoning Skills Pretest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	69.57	7.923	1.040
TG2	52	67.85	6.858	.951
CG1	42	70.67	6.203	.957

Note. Table 21 presents the descriptive statistics mean, standard deviation and standard error for the evaluation pretest scores for treatment group TG1, treatment group TG2, and control group CG1.

In Table 22 the descriptive statistics for treatment group TG1 posttest scores ($N = 58$, M = 74.26, SD = 7.371) treatment group TG2 posttest scores ($N = 52$, M = 70.98, SD = 6.661) and the control group CG1 posttest scores ($N = 42$, M = 72.12, SD = 7.750). Evaluation posttest subset scores for all three groups were in the moderate range.

A paired sample *t* test was completed to assess if there were any difference between posttest and pretest evaluation scores within groups. A Normal Q-Q plot was used to test the assumption of normality. The difference between inference posttest and pretest for treatment group TG1, treatment group TG2, and control group CG1 were normally distributed as assessed by visual inspection of a Normal Q-Q plot and by visual inspection of their histograms. One outlier was detected that was more than 1.5 box-lengths from the edge of the box in a boxplot. Examination of the value did not reveal it to be extreme, and it was kept in the analysis, as shown in Figure 7.

Table 22

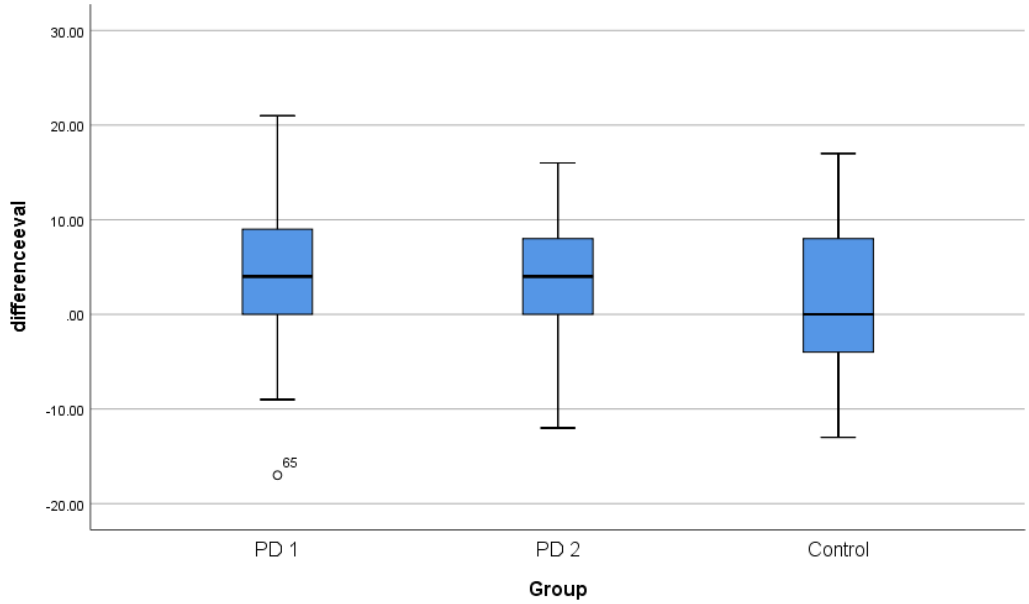
Evaluative Reasoning Skills Posttest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	74.26	7.371	.968
TG2	52	70.98	6.661	.924
CG1	42	72.12	7.750	1.196

Note. Table 22 presents the descriptive statistics mean, standard deviation, and standard error for the evaluation posttest scores for treatment group TG1, treatment group TG2, and control group CG1.

Figure 7

Outliers from Evaluative Reasoning Skills Difference Scores of Posttest-Pretest



Note. Figure 7 shows the outliers using evaluation difference scores, posttest minus pretest from the data set.

In table 23, the results of paired samples *t* tests examining the evaluative reasoning skills pretest scores and posttest scores for each group are found. There was a statistically significant

increase in evaluative reasoning post-test scores compared to pretest scores for treatment group TG1, M_{diff} = 4.690, 95% CI [1.005, 6.703], $t(57) = 6.455$, $p<.001$, d = 0.61. For treatment group TG2, there was a statistically significant increase in evaluative reasoning skills post-test scores compared to pretest scores, M_{diff} = 3.135, 95% CI [1.361, 4.908], $t(51)$, $p = 0.001$, d = .49. For the control group CG1, there was not a statistically significant increase in evaluative reasoning post-test scores compared to pretest scores, M_{diff} =1.452, 95% CI [-848, 3.753], $t(41)$, $p = 0.209$.

Table 23

Evaluative Reasoning Skills Pretest-Posttest Paired t Test Statistics

Group	Mean difference	sd	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	sig. (2-tailed)
TG1(*n*=58)	4.690	7.655	1.005	2.677	6.703	4.665	57	.000
TG2 (*n*=52)	3.135	6.371	.883	1.361	4.908	3.548	51	.001
CG1(*n*=42)	1.452	7.382	1.139	-.848	3.753	1.275	41	.209

Note. Table 23 presents the evaluative reasoning skills paired difference statistics, including mean difference, standard deviation, standard error, and upper and lower 95% Confidence Intervals for treatment group TG1, treatment group TG2, and control group CG1 using $\alpha < .05$.

An ANCOVA was run to determine if evaluative reasoning skills post-test scores were statistically different from pretest evaluative reasoning skills between the three groups: the control group and two treatment groups. There was a linear relationship between evaluative reasoning skills pre- and posttest for each group, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(2, 146) = 0.190$, p = .827. There were no outliers in the data, as with standardized residual greater than ±3 standard deviations. There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values. Standardized

residuals for the interventions were normally distributed for all groups, as assessed by Shapiro-Wilk's test ($p > .05$) for control group CG1 and assessed by visual inspection of Normal Q-Q Plots for treatment group TG1 and treatment group TG2. Shapiro-Wilk test is recommended for sample sizes of less than 50; determining normality for larger sample sizes is best suited by graphical methods, including Normal Q-Q plots and histograms (Lund Research Ltd, 2019).

Table 24

ANCOVA Estimates of Intervention and Control Results for Evaluative Reasoning Skills with Pretest as a Covariate

Group	Mean	Std. Error	95% CI Lower	95% CI Upper
TG1(*N*=58)	74.112[a]	.825	72.481	75.743
TG2(*N*=52)	71.716[a]	.878	69.982	73.450
CG1(*N*=42)	71.411[a]	.975	69.485	73.337

Note. Table 24 presents the ANCOVA estimates for evaluative reasoning skills statistics, including mean, standard error and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

a. Covariates appearing in the model are evaluated at the following values: Pre Evaluation = 69.28.

Table 25

Pairwise Comparison of Intervention and Control ANCOVA Results for Evaluation Scores with Pretest as a Covariate

Group	Group	Mean difference	Std. Error	Sig	95% CI Lower	95% CI Upper
TG1(*N*=58)	TG2 (*N*=52)	2.396	1.207	.147	-.525	5.318
TG2(*N*=52)	CG1(*N*=42)	.305	1.320	1.000	-2.890	3.500
TG1(*N*=58)	CG1(*N*=42)	2.701	1.276	.108	-.388	5.790

Note. Table 25 presents the evaluation score ANCOVA statistics, including mean difference, standard error, significance, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

After adjustment for the pretest, an ANCOVA found there was no statistically significant difference in analytical reasoning scores between any group, as shown in Table 25. $F(2,148) = 2.940$, $p = 0.056$, partial $n^2 = 0.038$. Post hoc analysis was performed with a Bonferroni adjustment, and Table 25 shows the pairwise comparison for the groups.

Research Question 5: Decision Making Skills

Research question five was to determine if there was a statistically significant difference in decision-making skills in participants in treatment group TG1, treatment group TG2, as compared to the control group CG1. Specifically, this question asked, “Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact decision-making skills of high school students as measured by the induction and deduction subset scores on the California Critical Thinking Skills Test?”

Table 26-29 shows the inductive and deductive decision-making skills pretest and posttest descriptive statistics for treatment group TG1, treatment group TG2, and the control group CG1.

In Table 26, the inductive decision-making skills descriptive statistics for treatment group TG1 pretest scores (N = 58, M = 71.03, SD = 8.612) Treatment group TG2 pretest scores (N = 52, M = 68.44, SD = 7.086) and the control group CG1 pretest scores (N = 42, M = 73.62, SD = 6.692) are presented. Inductive decision-making pretest scores for all three groups were in the weak to the moderate range — weak being between 63-69 and moderate being between 70-78 (Insight Assessment, 2019).

Table 26

Inductive Decision-Making Skills Pretest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	71.03	8.612	1.131
TG2	52	68.44	7.086	.983
CG1	42	73.62	6.692	1.033

Note. Table 26 presents the descriptive statistics mean, standard deviation, standard error for the inductive decision-making skills pretest scores for treatment group TG1, treatment group TG2, and control group CG1.

Table 27 shows the inductive decision-making skills descriptive statistics for treatment group TG1 posttest scores (N = 58, M = 76.55, SD = 7.701) treatment group TG2 posttest scores (N = 52, M = 72.10, SD = 5.457) and the control group CG1 posttest scores (N = 42, M = 73.67, SD = 7.647). Inductive decision-making post-test scores for all three groups were in the moderate range for overall critical thinking skills, the moderate being between 70-78 (Insight Assessment, 2019).

Table 27

Inductive Decision-Making Skills Posttest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	76.55	7.701	1.011
TG2	52	72.10	5.457	.757
CG1	42	73.67	7.647	1.180

Note. Table 27 presents the descriptive statistics mean, standard deviation, and standard error for the inductive decision-making skills posttest scores for treatment group TG1, treatment group TG2, and control group CG1.

In Table 28, the deductive decision-making skills descriptive statistics for treatment group TG1 pretest scores ($N = 58$, M = 70.05, SD = 7.087) treatment group TG2 pretest scores ($N = 52$, M = 67.23, SD = 5.451) and the control group CG1 pretest scores ($N = 42$, M = 71.69, SD = 6.531) are presented. Deductive decision-making pretest scores for all three groups were in the weak to the moderate range — weak being between 63-69 and moderate being between 70-78 (Insight Assessment, 2019).

Table 28

Deductive Decision-Making Skills Pretest Descriptive Statistics

Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	70.05	7.087	.931
TG2	52	67.23	5.451	.756
CG1	42	71.69	6.531	1.008

Note. Table 28 presents the descriptive statistics mean, standard deviation, and standard errror for the deductive decision-making skills pretest scores for treatment group TG1, treatment group TG2, and control group CG1.

Table 29 displays the deductive decision-making skills descriptive statistics for treatment group TG1 posttest scores ($N = 58$, M = 73.71, SD = 7.289) Treatment group TG2 posttest scores ($N = 52$, M = 68.85, SD = 7.086) and control group CG1 posttest scores ($N = 42$, M = 73.79, SD = 8.581). Deductive decision-making skills post-test scores for all three groups were in the weak to moderate range.

Table 29

Deductive Decision-Making Skills Posttest Descriptive Statistics

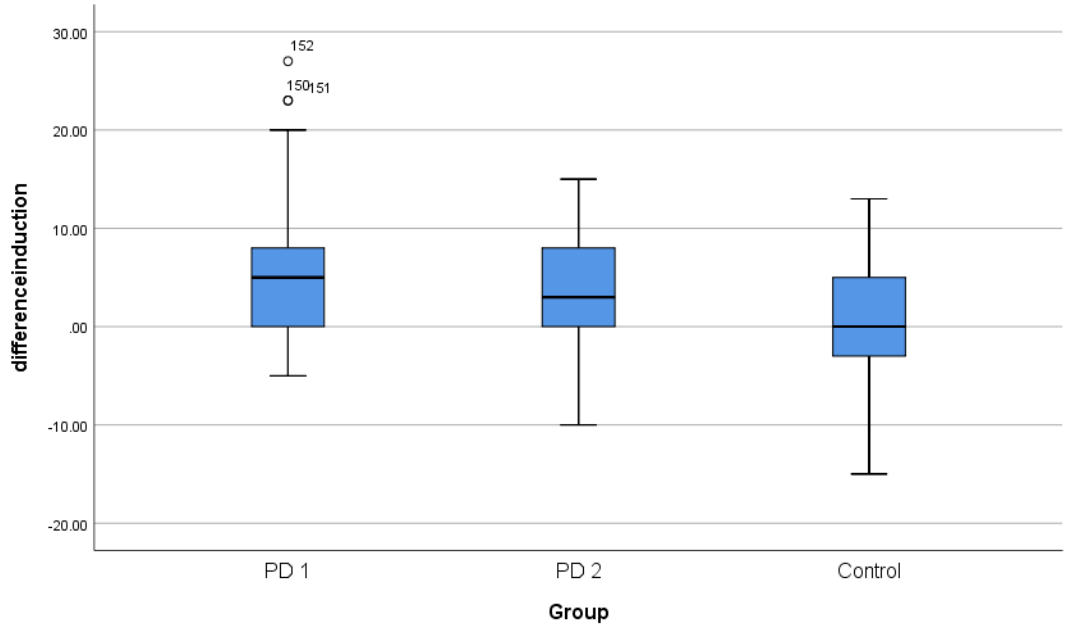
Group	*N*	Mean	Standard Deviation	Std. Error Mean
TG1	58	73.71	7.289	.957
TG2	52	68.85	7.086	.983
CG1	42	73.79	8.581	1.324

Note. Table 29 presents the descriptive statistics mean, standard deviation and standard error for the deductive decision-making skills posttest scores for treatment group TG1, treatment group TG2, and control group CG1.

Tables 30 and 31 present the results of paired-samples *t* tests examining the inductive and deductive decision-making skills pretest scores and posttest scores for each group. For inductive reasoning skills, a Normal Q-Q plot was used to test the assumption of normality. The difference between inference posttest and pretest for treatment group TG1, treatment group TG2, and the control group CG1 were normally distributed as assessed by visual inspection of a Normal Q-Q plot and by visual inspection of their histograms. For inductive reasoning skills difference scores, three outliers were detected that were more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of the values did not reveal them to be extreme, and they were kept in the analysis, as shown in Figure 8.

Figure 8

Outliers from Inductive Decision Making Skills Difference Scores of Posttest-Pretest

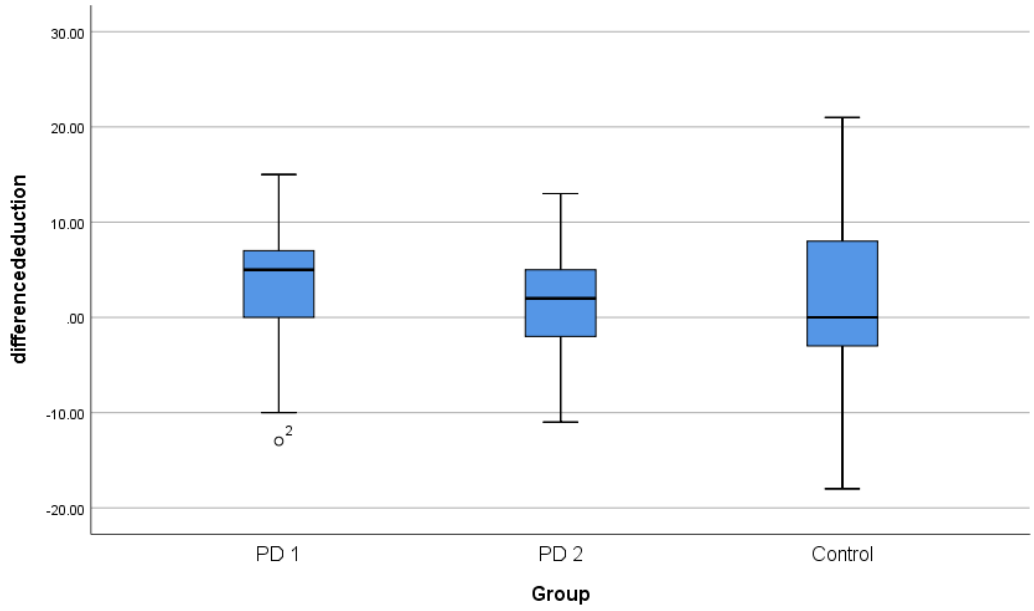


Note: Figure 8 shows the outliers using difference scores, posttest minus pretest from the data set.

For deductive reasoning skills, a Normal Q-Q plot was used to test the assumption of normality. The difference between inference posttest and pretest for treatment group TG1, treatment group TG2, and the control group CG1 were normally distributed as assessed by visual inspection of a Normal Q-Q plot and by visual inspection of their histograms. One outlier was detected that was more than 1.5 box-lengths from the edge of the box in a boxplot. A review of the value did not reveal it to be extreme, and it was kept in the analysis, as shown in Figure 9.

Figure 9

Outliers from Deductive Decision-Making Skills Difference Scores of Posttest-Pretest



Note: Figure 9 shows the outliers using deductive reasoning skills difference scores, posttest minus pretest from the data set.

As seen in data from Table 30, there was a statistically significant increase in inductive decision-making skills post-test scores compared to pretest scores for treatment group TG1, M_{diff} = 5.517, 95% CI [3.753, 7.282], $t(57) = 6.262$, $p<.0001$, d = 0.82. For treatment group TG2, there was a statistically significant increase in inductive decision-making skills post-test scores compared to pretest scores, M_{diff} = 3.654, 95% CI [2.088, 5.220], $t(51)$, $p<0.001$, d =.65.

For the control group CG1, there was not a statistically significant increase in inductive decision-making skills post-test scores compared to pretest scores, $M_{diff} = 0.045$, 95% CI [-2.003, 2.099], $t(41)$, $p = 0.963$.

Table 30

Inductive Decision-Making Skills Pretest-Posttest Paired t Test Statistics

Group	Mean difference	sd	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	sig. (2-tailed)
TG1(*n*=58)	5.517	6.710	.881	3.753	7.282	6.262	57	.000
TG2 (*n*=52)	3.654	5.625	.780	2.088	5.220	4.684	51	.000
CG1(*n*=42)	.048	6.581	1.016	-2.003	2.099	.047	41	.963

Note. Table 30 presents the paired difference statistics for inductive decision-making skills, including mean difference, standard deviation, standard error, and upper and lower 95% Confidence Intervals for treatment group TG1, treatment group TG2, and control group CG1 using $\alpha < .05$.

As seen from the data in Table 31, there was a statistically significant increase in deductive decision-making post-test scores compared to pretest scores for treatment group TG1, $M_{diff} = 3.655$, 95% CI [2.282, 5.029], $t(57) = 5.329$, $p<.001$, d = 0.69. For treatment group TG2, there was a statistically significant increase in deductive decision making skills post-test scores compared to pretest scores, $M_{diff} = 1.615$, 95% CI [.026, 3.205], $t(51) = 2.040$, $p = 0.047$, d = .28. For the control group CG1, there was not a statistically significant increase in deductive decision-making skills post-test scores compared to pretest scores, $M_{diff} = 2.095$, 95% CI [-.359, 4.550], $t(41)$, $p= 0.092$, d =.27.

Table 31

Deductive Decision-Making Skills Pretest-Posttest Paired t Test Statistics

Group	Mean difference	sd	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	sig. (2-tailed)
TG1(*n*=58)	3.655	5.223	.686	2.282	5.029	5.329	57	.000
TG2 (*n*=52)	1.615	5.709	.792	.026	3.205	2.040	51	.047
CG1(*n*=42)	2.095	7.877	1.215	-.359	4.550	1.724	41	.092

Note. Table 31 presents the paired difference statistics, including mean difference, standard deviation standard error, and upper and lower 95% Confidence Intervals for treatment group TG1, treatment group TG2, and control group CG1 using $\alpha < .05$.

Two ANCOVAs were run to determine if decision-making skills, including both inductive and deductive decision-making skills, post-test scores were statistically different between the pretest inductive and deductive reasoning skills in the control group and two treatment groups. For inductive decision-making skills, there was a linear relationship between pretests and posttests for each group, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(2, 146) = 0.607$, $p = .546$. There were no outliers in the data with standardized residual greater than ±3 standard deviations. There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values. Standardized residuals for the interventions were normally distributed for all groups, as assessed by Shapiro-Wilk's test ($p > .05$) for the control group CG1 and assessed by visual inspection of Normal Q-Q Plots for treatment group TG1 and treatment group TG2. Shapiro-Wilk test is recommended for sample sizes of less than 50; determining normality for larger sample sizes is best suited by graphical methods, including Normal Q-Q plots and histograms (Lund Research Ltd, 2019).

For deductive decision-making skills, there was a linear relationship between deductive decision-making skills pretest and posttest for each group, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(2,146) = 0.334$, $p = .716$. There were no outliers in the data with standardized residual greater than ±3 standard deviations. There was homoscedasticity, as assessed by visual inspection of the standardized residuals plotted against the predicted values. Standardized residuals for the interventions were normally distributed for all groups, as assessed by Shapiro-Wilk's test ($p > .05$) for CG1 and assessed by visual inspection of Normal Q-Q Plots for treatment group TG1 and treatment group TG2. Shapiro-Wilk test is recommended for sample sizes of less than 50; determining normality for larger sample sizes is best suited by graphical methods, including Normal Q-Q plots and histograms (Lund Research Ltd, 2019). Post hoc analysis was performed with a Bonferroni adjustment, and Tables 32 and 33 show the estimates considering the covariate and the pairwise comparison for inductive reasoning skills for the groups.

Table 32

ANCOVA Estimates of Intervention and Control Results for Inductive Decision Making Skills with Pretest as a Covariate

Group	Mean	Std. Error	95% CI Lower	95% CI Upper
TG1(*N*=58)	76.451[a]	.728	75.013	77.889
TG2(*N*=52)	73.506[a]	.783	71.959	75.053
TG1(*N*=58)	72.060[a]	.872	70.337	73.783

Note. Table 32 presents the ANCOVA estimates for inductive decision-making skills statistics, including mean, standard error, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

a. Covariates appearing in the model are evaluated at the following values: Pre Induction = 70.86.

Table 33

Pairwise Comparison of Intervention and Control ANCOVA results for Inductive Decision-Making Scores with Pretest as a Covariate

Group	Group	Mean difference	Std. Error	Sig	95% CI Lower	95% CI Upper
TG1(*N*=58)	TG2 (*N*=52)	2.945	1.070	.020	.354	5.537
TG2(*N*=52)	CG1(*N*=42)	1.446	1.193	.682	-1.443	4.335
TG1(*N*=58)	CG1(*N*=42)	4.391	1.134	.000	1.645	7.137

Note. Table 33 presents the inductive decision-making skills ANCOVA statistics, including mean difference, standard error, significance, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

After adjustment for the pretest, there was a statistically significant difference in inductive reasoning skills post-test between treatment group TG1 and the control group CG1. Treatment group TG1 (M = 76.45) is significantly higher than the control group CG1 (M = 72.06), with a mean difference of 4.391, 95% CI [1.645, 7.137], $p<0.001$. After adjustment for the pretest, there was a statistically significant difference in inductive reasoning skills post-test between treatment group TG1 and treatment group TG2. Treatment group TG1 (M = 72.06) is statistically significantly different than treatment group TG2 (M = 73.51), with a mean difference of 2.945, 95% CI [0.354, 5.537], $p = 0.02$.

There were no statistically significant differences among groups concerning deductive reasoning skills $F(2,148) = 2.880$, $p = 0.059$, partial $n^2 = 0.037$, as shown in Table 34.

Table 34

Pairwise Comparison of Intervention and Control ANCOVA results for Deductive Decision-Making Scores with Pretest as a Covariate

Group	Group	Mean difference	Std. Error	Sig	95% CI Lower	95% CI Upper
TG1(*N*=58)	TG2 (*N*=52)	2.795	1.165	.053	-.027	5.617
TG2(*N*=52)	CG1(*N*=42)	-1.674	1.290	.590	-4.798	1.450
TG1(*N*=58)	CG1(*N*=42)	1.121	1.221	1.000	-1.836	4.079

Note. Table 34 presents the deductive decision-making skills ANCOVA statistics, including mean difference, standard error, significance, and 95% Confidence Interval for lower and upper bounds for treatment group TG1, treatment group TG2, and control group CG1.

Decision-making skills include both deductive decision making skills and inductive decision making skills. A statistical difference was found in inductive decision making skills of advanced level high school students whose teachers were enrolled in PD1 (a 15 week, structured

asynchronous online professional development course by the Foundation of Critical Thinking) compared to the critical thinking skills of advanced level high school students whose teacher was enrolled in PD2 (a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates) $F(2,148) = 8.288$, $p<0.001$, partial $n^2 = 0.101$. Advanced level high school students with teachers enrolled in PD1, a structured asynchronous online professional development course, showed a statistically significant increase from a control group in inductive decision making skills as measured by the California Critical Thinking Skills Test (CCTST). There were no differences found between groups' deductive decision-making skills.

Teacher Survey Frequencies

Teachers that participated in the professional development took a survey each month during the semester, reporting the frequency of access and use of elements concerning critical thinking skills. They answered questions based on the incorporation of critical thinking skills into their classrooms. Table 35 below summarizes their responses.

Table 35

Survey Frequencies of Monthly Responses from Teachers

Survey Question	Daily (%)	At least once a week (%)	2 to 3 times a month (%)	Once a month (%)	Never (%)
How frequently did you access the professional development material?	0	25.0	45.8	29.2	0
The lessons I learned in my critical thinking course informed/influenced my lesson planning	0	4.2	45.8	50.0	0
I incorporated analytical reasoning skills into my lectures	0	50.0	41.7	8.3	0
I incorporated analytical reasoning skills into my tests	0	4.2	54.2	29.2	12.5
I incorporated analytical reasoning skills into my quizzes	8.3	20.8	54.2	8.3	8.3
I incorporated analytical reasoning skills into assignments	0	16.7	50.0	16.7	16.7
I incorporated analytical reasoning skills into labs/projects	0	12.5	41.7	45.8	0
I incorporated inference skills into my lectures	33.3	41.7	16.7	8.3	0
I incorporated inference skills into my tests	0	0	37.5	50.0	12.5
I incorporated inference skills into my quizzes	16.7	0	41.7	25.0	16.7
I incorporated inference skills into assignments	16.7	29.2	20.8	20.8	12.5
I incorporated inference skills into labs/projects	0	33.3	16.7	33.3	16.7

I incorporated evaluative reasoning skills into my lectures	0	33.3	16.7	16.7	8.0
I incorporated evaluative reasoning skills into my tests	0	0	16.7	50.0	33.3
I incorporated evaluative reasoning skills into my quizzes	0	16.7	16.7	16.7	50.0
I incorporated evaluative reasoning skills into assignments	0	12.5	25.0	29.2	33.3
I incorporated evaluative reasoning skills into labs/projects	0	20.8	20.8	25.0	33.3

I incorporated decision making skills into my lectures	0	62.5	37.5	0	0
I incorporated decision making skills into my tests	0	0	70.8	29.2	0
I incorporated decision making skills into my quizzes	16.7	0	62.5	20.8	0
I incorporated decision making skills into assignments	37.5	20.8	29.2	12.5	0
I incorporated decision making skills into labs/projects	20.8	20.8	20.8	20.8	16.7

Note: Table 35 presents survey frequencies for teacher participant survey data.

The table reflects a culmination of all the surveys gathered during the semester. Looking at the survey question, "I incorporated decision-making skills into labs/projects," 20.8% of responses said they never incorporated decision-making skills during that month. The response of 20.8% does not reflect that the teachers never incorporated decision-making skills into labs/projects during the entire professional development period. During the period of one month, 20.8% of teachers did not incorporate decision-making skills into labs/projects.

Conclusion

This research implemented a quantitative between group research design and utilized dependent *t* tests as well as ANCOVAs to compute statistical differences among and between groups. Data gained from the 152 participants were analyzed to assess five research questions:

(1) Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact critical thinking skills of high school students taking college preparatory classes as measured by the overall score on the California Critical Thinking Skills Test?, (2) Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact analytical reasoning skills of high school students taking college preparatory classes as measured by the analysis subset score on the California Critical Thinking Skills Test?, (3) Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact inference skills of high school students as measured by the inference subset score on the California Critical Thinking Skills Test?, (4) Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact evaluative reasoning skills of high school students as measured by the evaluation subset score on the California Critical Thinking Skills Test?, (5) Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact decision-making skills of high school students as measured by the induction and deduction subset scores on the California Critical Thinking Skills Test?

Advanced level high school students with teachers enrolled in PD1 (a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) showed a statistically significant increase from a control group in overall critical thinking skills, analytical reasoning skills, inference skills, and inductive decision making skills as measured by the California Critical Thinking Skills Test (CCTST). A statistical difference was also found in overall critical thinking skills and inductive decision making skills of advanced level high school students whose teachers were enrolled in PD1, a structured asynchronous online professional development course, compared to the overall critical thinking skills and inductive decision

making skills of advanced level high school students whose teacher was enrolled in PD22, an asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates.

Chapter V

Discussion

Introduction

Critical thinking is an essential life skill, (Nirmala & Kumar, 2018; Paul, Elder & Bartell, 1997; ten Dam, & Volman, 2004; Williams, 2005), yet there is a lack of critical thinking skills in our graduating students (Glaser, 1984; National Education Goals Panel, 1992; Schneider & Miller, R, 2005). Although some studies have shown that students' critical thinking skills can increase (Solon, 2007; Wulandari et al., 2017), very few studies have examined the role professional development can play in increasing these skills in high school students. Many teachers agree that teaching critical thinking skills is essential, yet professional development in the area of critical thinking is deficient and not readily accessible (Bedosky, 2013; Nicholas & Raider-Roth, 2016), and they lack the training to teach critical thinking skills (As'ari et al., 2017; Cansoy & Türkoglu, 2017; Geçit & Akarsu, 2017; Taylor et al., 2017; Whittington, 1995). The majority of currently offered professional development has minimal instruction and often leaves the instructor with no concrete way to integrate the knowledge into the classroom (Banilower et al., 2007; Bedosky, 2013; Gerard et al., 2011). The content focused, semester-long professional developments used in this study employed a flexible format and were implemented over a semester where teachers actively learned how to incorporate critical thinking skills into the classroom.

The purpose of this study was to explore if teacher participation in critical thinking professional development impacted critical thinking skills in high school students. The results of this study could have effects as the study found that in some areas, teachers are able to integrate the information they have learned into their classrooms to a point where a measurable difference

in critical thinking skills is found in their students. This study could help provide direction for high-quality professional development in a subject that is currently underprovided in professional development (Bedosky, 2013; Smith et al., 2003; Van der Werff, 2016).

The participants in this study included high school teachers, who were selected via convenience sampling, and their students. The teachers were 67% women and 42% men with an average age of 41 years old, and an average of twelve years of teaching experience, possessed various teaching styles and had varying levels of education and various backgrounds. High schools were selected for the setting, and the schools chosen were based on the study criteria discussed in chapter 3.

A quantitative between-group design included two treatment groups and a control group CG1. Treatment group TG1 included 58 students from three class sections, and the teachers in this group enrolled in an online critical thinking professional development course where they were assigned homework and reading and were part of discussion groups. Treatment group TG2 consisted of 52 students and three class sections, and the teachers enrolled in a self-guided video-based professional development course where they watched a series of videos. Both professional development treatments consisted of the same information. The control group CG1 included 42 students from four class sections. The teachers of the control group students did not participate in any critical thinking professional development during the semester.

The student study population contained 74 (48.7%) females and 76 (50%) male. The ages of the student participants ranged from 16-19 years, consisting of 95 (62.5%) junior-level students and 57 (37.5%) senior-level students. The population contained 69 students (45.4%) with a GPA above 4.0, 52 students (34.5%) with a GPA between 3.5-3.9, 23 students (15.1%) with a GPA between 2.5-2.99, 7 students (4.6%) with a GPA between 2.1-2.49, and one student

(0.7%) with a GPA under 2.0. The majority of participants reported White Caucasian, Anglo American (*N* = 66, 54.6%), followed by Asian, Asian American, Pacific Islander (*N* = 45, 29.6%), Hispanic, Latino, Mexican American (*N* = 18, 11.8%), Black, African American (*N* = 6, 3.9%), American Indian/Native American (*N* = 1, 0.7%), Other (*N* = 6, 3.9%) and participants that chose not to provide this information (*N* = 10, 6.6%).

Statistics, including *t* tests, and ANCOVAs in addition to descriptive statistics using SPSS software, were performed at the conclusion of the study. Data was uploaded to SPSS after pretest and posttest data were collected from the three groups. Sample demographics were obtained from sample data. To test each hypothesis, dependent *t* tests were conducted comparing mean pretest scores to mean posttest scores. ANCOVAs were run for each hypothesis to explore if there were any differences in critical thinking skills between the groups adjusting for the covariate, pretest scores. Overall the results of the statistical analysis supported the purpose of the research which was to determine if student critical thinking skills were impacted when teachers engaged in the long term critical thinking professional development as measured by the California Critical Thinking Skills Test. A discussion of the results and hypotheses follows.

Research Questions

The primary purpose of this study was to determine if there were differences in students' critical thinking scores among the three groups, treatment group TG1, treatment group TG2, and the control group CG1 after the teachers in the treatment groups participated in critical thinking professional development. Therefore, for the purpose of this study, five principal research questions were explored. These questions included:

RQ1: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact critical thinking skills of high school students taking

college preparatory classes as measured by the overall score on the California Critical Thinking Skills Test?

RQ2: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact analytical reasoning skills of high school students taking college preparatory classes as measured by the analysis subset score on the California Critical Thinking Skills Test?

RQ3: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact inference skills of high school students as measured by the inference subset score on the California Critical Thinking Skills Test?

RQ4: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact evaluative reasoning skills of high school students as measured by the evaluation subset score on the California Critical Thinking Skills Test?

RQ5: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact decision-making skills of high school students as measured by the induction and deduction subset scores on the California Critical Thinking Skills Test?

Summary of the Results

Chapter five provides the study's results and interpretations. This chapter summarizes the overview of the research methodology, the participant demographics, the research questions, and hypotheses and any significant statistical findings related to the research questions. In addition, the researcher will discuss recommendations for further research, limitations of the study, and any implications the study's findings have on students' critical thinking skills.

Question one examines students' overall critical thinking. For questions two through five, the subsets measured are not meant to be treated as independent factors yet are reflections of a segment of the greater holistic conceptualization of students' critical thinking skills, including analytical reasoning skills, inference skills, evaluative reasoning skills, and decision-making skills. These research questions help identify the students' specific strengths and weaknesses, and the results from these questions help educators and administrators address particular aspects of critical thinking skills for future educational opportunities. These subsets were selected as they contain parts of the four major components to critical thinking, which include reasoning, intellectual standards, analytical inferential skills and traits and dispositions (Paul, Elder & Bartell, 1997). Reasoning occurs in the context of intellectual standards, which encompass accuracy, precision, relevance, clarity, logic, breadth, and depth (Paul, Elder & Bartell, 1997). Analytic inferential skills include the ability to formulate and assess goals, information, problems, data, assumptions, consequences, frames of reference, and varied points of view (Paul, Elder & Bartell, 1997).

Research Question #1: Summary of Results and Discussion

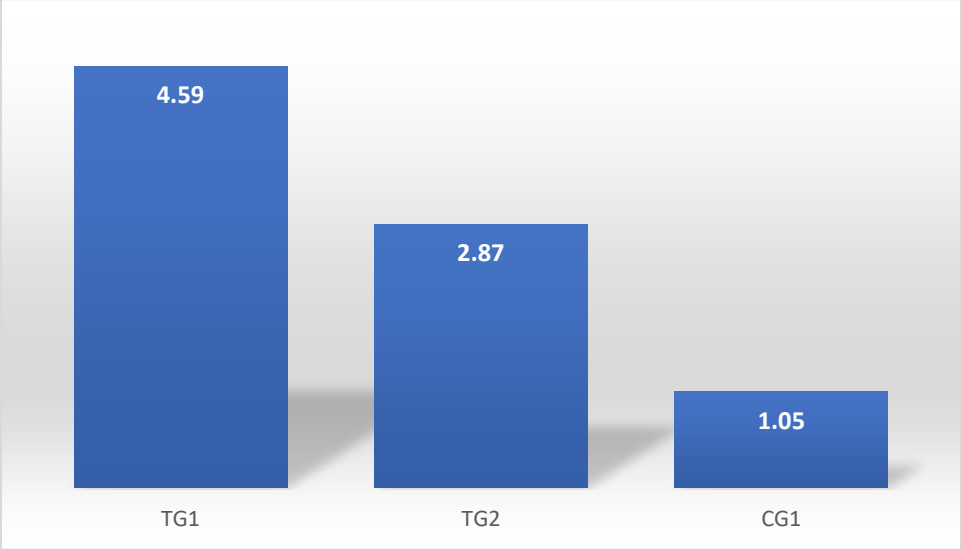
The first question guiding this research was: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact critical thinking skills of high school students taking college preparatory classes as measured by the overall score on the California Critical Thinking Skills Test? The overall critical thinking score encompasses the student’s strength in using reasoning to make judgments about what to believe (Insight Assessment, 2019). This score includes all the subsets, including analysis, interpretation, inference, evaluation, explanation, induction, and deduction.

Pretest and posttest data suggested that when teachers participated in either the PD1(a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) or the PD2 (a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates), advanced level high school students overall critical thinking skills statistically increased as measured by the California Critical Thinking Skills Test (Table 8, page 91). Students in the control group CG1 whose teachers did not participate in the professional development saw no statistically significant increase in overall critical thinking skills. Advanced level high school students overall critical thinking skills for both treatment group TG1 and in treatment group TG2 increased while the control group CG1 did not statistically increase based on pretest posttest results from a paired *t* test.

Differences were also seen between groups. Advanced level high school students with teachers enrolled in PD1 (a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) showed a statistically significant increase from a control group in overall critical thinking skills as measured by the California Critical Thinking Skills Test. A statistical difference was also found in the overall critical thinking skills of advanced placement high school students whose teachers were enrolled in PD1, a structured asynchronous online professional development course by the Foundation of Critical Thinking) compared to the overall critical thinking skills of advanced placement high school students whose teacher was enrolled in PD2, an asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates as measured by the California Critical Thinking Skills Test.

Figure 10

Overall Critical Thinking Skills Gain from Pretest to Posttest



Note. Figure 10 scores are shown as gain scores (posttest-pretest scores) for the differences in overall critical thinking skills out of a total possible score of 100. TG = Treatment Group, CG = Control Group. Data from this figure is located in Table 8, page 91.

Other studies that examined growth in critical thinking skills saw similar results. The teachers in intervention groups one and two learned how to infuse explicit critical thinking skills into their classes over a semester, and students' overall critical thinking skills increased. When students receive explicit training on how to apply critical thinking skills, they can increase their critical thinking skills (Abrami et al., 2008; Cone et al., 2016; Gunn et al., 2008; Heijltjes et al., 2015; Ghanizadeh, 2017; Marin & Halpern, 2011; Sanavi & Tarighat, 2014; Solon, 2007). A literature review based on critical thinking studies from 1994-2009 also found that the longer the experimental treatment was, the greater the likelihood of statistically significant changes in critical thinking skills (Behar-Horenstein & Niu, 2011). The results of

this semester-long study did show a statistical increase in critical thinking skills in both treatment groups. The experimental treatment in this study was a semester, which may have increased the likelihood of seeing a statistically significant difference in student critical thinking skills. In a five-year study by Toppin and Chitsonga (2016), faculty were given a manual on critical thinking skills but did not receive any professional development. Although some students did improve their critical thinking skills, there was no clear increase in students' skills.

Some studies did not show the same gain in critical thinking skills as this study did. Agdas (2013) saw no increase in overall critical thinking skills, but the intervention time was only four weeks from pretest to posttest. Phelan (2012) studied student critical thinking skills in a higher education technology course over twelve weeks but did not see a statistical increase in students' critical thinking skills. There was no professional development offered in this study. In a study by McGuire (2010), teachers received one week of professional development training in teaching critical thinking skills, and the results showed no statistically significant increase in student critical thinking skills. Perhaps the longer intervention time on both the study duration and the teacher professional development allowed for the students to learn and integrate critical thinking skills at a rate that could be measured on the California Critical Thinking Skills Test.

There is little data exploring the effects of professional development on student critical thinking skills. Abrami et al. (2008) found, "To maximize impact requires both the willingness to incorporate critical thinking instruction and explicit strategies and skills to do it effectively" (p. 1121). When educators have clear critical thinking objectives and integrate critical thinking into their courses, students' critical thinking skills improve according to the study by Abrami et

al. (2008). The optimal way to advance critical and reflective thinking is by designing a curriculum that applies an activist approach on the part of the instructor (Henderson Hurley & Hurley, 2013). Teachers can increase students' critical thinking skills by including instructional interventions that explicitly teach critical thinking skills while incorporating opportunities for students to practice those skills (Heijltjes et al., 2014). This can be as little time as 15 minutes to teach a lesson and 20 minutes to practice the new skills. Effective critical thinking instruction has a structure that includes effective student engagement for a period of time where a specific skill is introduced, requires deliberate practice, and provides an opportunity for the students to transfer the knowledge (Marin & Halpern, 2011). Teachers who have not been taught how to incorporate critical thinking skills into their teaching effectively are unable to effectively teach students how to apply these skills (Smith & Szymanski, 2013; Whittington, 1995; Williams, 2005).

There is little data available about studying different modes of professional development that contain the same information and student outcomes. Treatment group TG1 and treatment group TG2 overall critical thinking skills were statistically different from each other based on posttest means analyzed using an ANCOVA. Advanced level high school students with teachers enrolled in PD1 (a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) statistically increased their overall critical thinking skills when compared to the overall critical thinking skills of advanced placement high school students whose teacher was enrolled in PD2 (a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates). Treatment group TG1 and the control group CG1 overall critical thinking skills were statistically different from each other based on

posttest means analyzed using an ANCOVA. Advanced level high school students with teachers enrolled in PD1, a structured asynchronous online professional development course by the Foundation for Critical Thinking, showed a statistically significant increase from a control group CG1 in overall critical thinking skills as measured by the California Critical Thinking Skills Test. Still, this statistical difference was not apparent in all critical thinking subscales. It is interesting to note that while the control group CG1 started with the highest level of overall critical thinking skills, that group showed the least improvement of the three groups.

Research Question #2: Summary of Results and Discussion

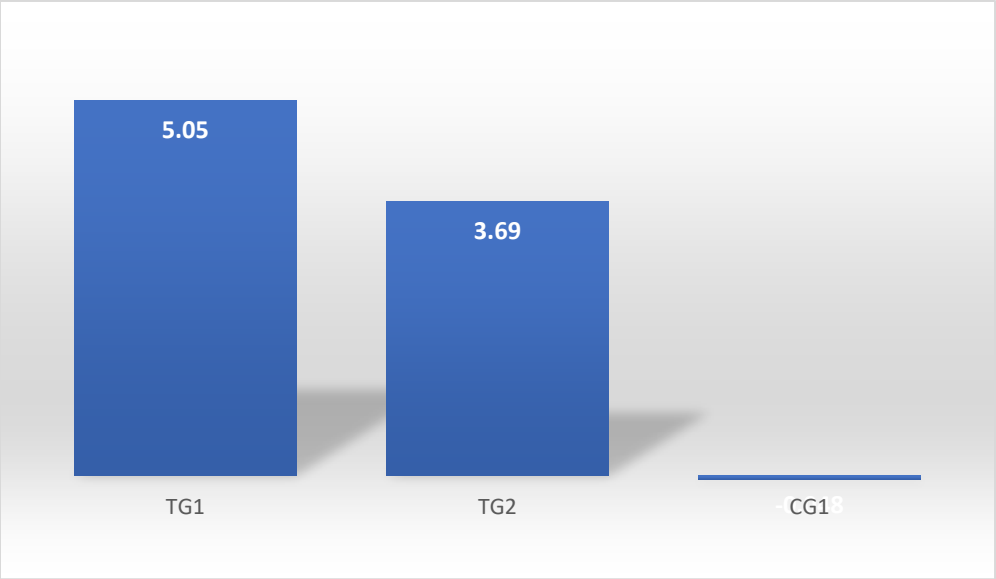
The second question guiding this research was: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact analytical reasoning skills of high school students taking college preparatory classes as measured by the analysis subset score on the California Critical Thinking Skills Test? The analysis subset encompasses students' analytical reasoning skills, which include how people identify assumptions, claims, and reasons and enable them to examine how these interact in the formation of arguments. (Insight Assessment, 2019). Students access analytical reasoning skills when they gather information from spoken languages, diagrams, graphs, charts, and documents.

Advanced level high school students' analytical reasoning skills in both treatment group TG1 and treatment group TG2 increased while the control group CG1 did not statistically increase (see Figure 11). Other studies did not see a statistically significant increase in the analysis subset scores. Cone et al. (2016) studied 83 first year pharmacy students and found that their analysis skills did not show a statistically significant increase from pretest to posttest. Phelan (2012) studied twenty participants over a ten-week period in a higher education

technology course and found no statistical increase in analytical reasoning scores from pretest to posttest. McGuire (2010) studied 15 college students over the course of one semester, and Agdas (2013) studied 45 college students over the course of a one semester engineering course.

Figure 11

Gain in Analytical Reasoning Skills from Pretest to Posttest



Note. Scores are shown as gain scores (posttest-pretest scores) for the differences in analytical reasoning skills out of a total possible score of 100. TG = Treatment Group, CG = Control Group. Data from this figure is located in chapter 4, Table 13, page 98.

There was no statistical difference between the two treatment groups TG1, advanced level high school students with teachers enrolled in PD1 (a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) and TG2, advanced high school students with teachers enrolled in PD2 (a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates) in terms of analytical reasoning skills. Yet, treatment group

TG1 and the control group CG1 did show a statistical difference between the two groups based on posttest means analyzed using an ANCOVA. (Table 13, page 98).

Students increased their analytical reasoning abilities, which means they increased their proficiency in gathering information and identifying assumptions and claims from documents, graphs, or charts. The control group virtually remained unchanged from pretest to posttests. The control group had the highest pretest scores in the analytical reasoning skills of the three groups, and their scores were in the moderate range (Table 11, page 95).

Research Question #3: Summary of Results and Discussion

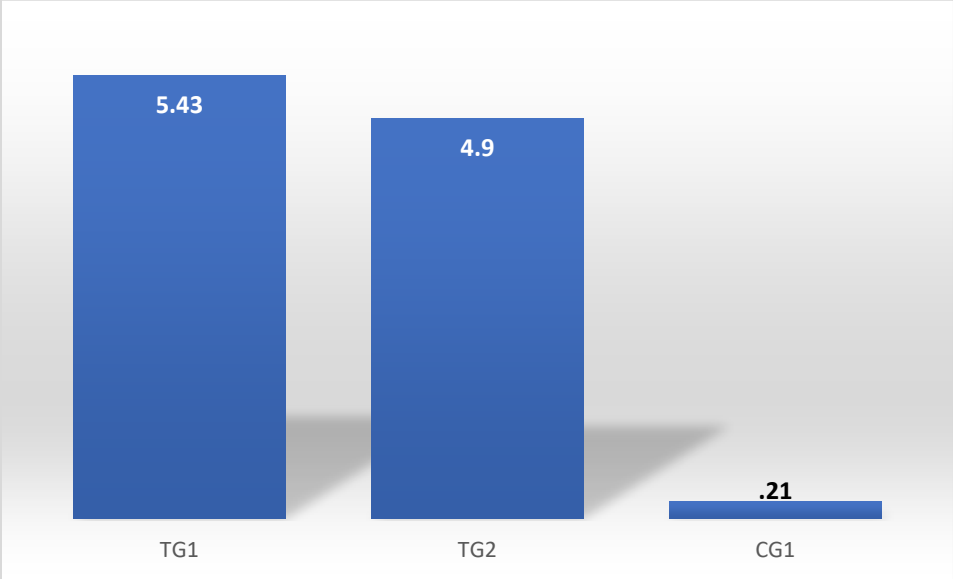
The third question guiding this research was: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact inference skills of high school students as measured by the inference subset score on the California Critical Thinking Skills Test? Being a critical thinker includes objectively assessing personal views and the views of others, conceiving alternative choices, having reliable observations, and making sound inferences (Norris, 1985). Inference skills enable students to draw conclusions from evidence or facts. Students use these skills when making thoughtful suggestions and hypotheses, and they help students to determine the consequences of a given set of facts or conditions (Insight Assessment, 2019).

Although it was a different population, second-year pharmacy students, the study by Cone et al., (2016) found similar results. After a 16-week intervention on explicit critical thinking skills, pharmacy school students increased their inference skills. Other studies that examined changes in students' inference skills did not see a statistically significant difference from pretest to posttest scores (Agdas, 2013; McGuire, 2010; Phelan, 2012). Both treatment group, TG1 which consisted of advanced high school students with teachers, enrolled in PD1 (a

15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) and treatment group TG2 which consisted of advanced high school students with teacher enrolled in PD2 (a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates) statistically increased their inferences skills while the control group CG1 did not statistically increase (see Figure 12).

Figure 12

Gain in Inference Skills from Pretest to Posttest Scores



Note. Scores are shown as gain scores (posttest-pretest scores) for the differences in inference skills out of a total possible score of 100. TG = Treatment Group, CG = Control Group. Data from this figure is located in chapter 4, Table 18, page 104.

When controlling for the pretest, the covariate, there was no statistical difference between treatment group TG1 and treatment group TG2 regarding inference skills. The only statistical difference between any group was between treatment group TG1 and the control group CG1 based on posttest means analyzed using an ANCOVA. (Table 20, page 105).

In 1983 the publication *A Nation at Risk* reported that 40% of students lacked critical thinking skills needed to make inferences from written material (Willingham, 2008). The results from this study suggest that when teachers participated in either PD1, a structured asynchronous online professional development course or PD2, self-paced video-based asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates, advanced level high school students became more proficient at inference skills, including drawing conclusions from evidence or facts than did the control group participants.

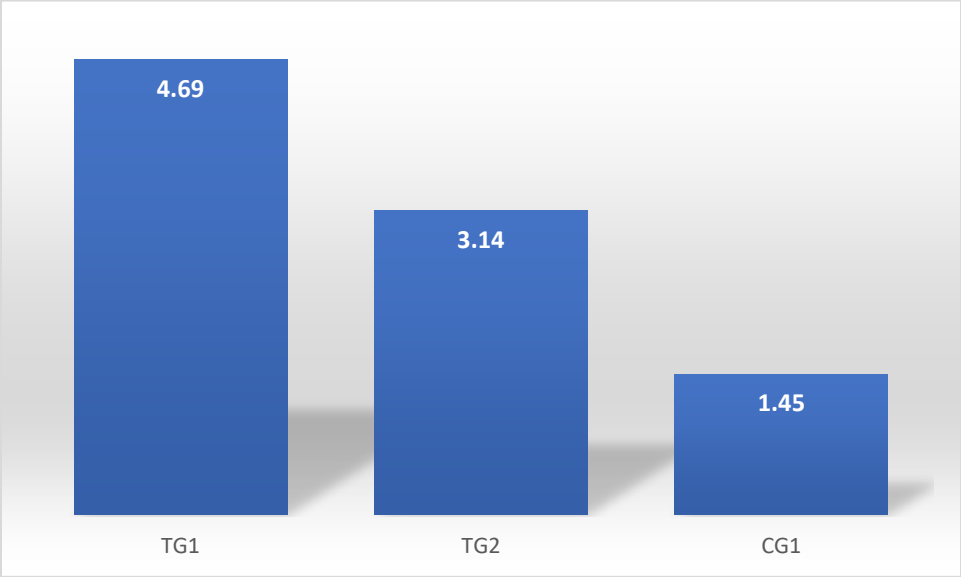
Research Question #4: Summary of Results and Discussion

The fourth question guiding this research was: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact evaluative reasoning skills of high school students as measured by the evaluation subset score on the California Critical Thinking Skills Test? Evaluation is included in Bloom's taxonomy and is an essential part of higher-order thinking (Newcom & Trezf, 1987). According to Bloom (1956), evaluation includes making judgments and assessing the value of ideas, solutions, methods, arguments, or ideas. Students use evaluative reasoning skills when assessing the credibility of claims and the credibility of sources of information. Evaluative reasoning skills facilitate students' abilities to determine the quality of explanations, reasons, and decisions while assessing the weaknesses and strengths of arguments (Insight Assessment, 2019). While all three groups showed increases in evaluative reasoning skills, only treatment group TG1 and treatment group TG2 resulted in statistically significant increases from pretest to posttest scores (Table 23, page 110). Figure 13 illustrates the gain in evaluative reasoning skills for each of the groups. Although it was a different population, second-year pharmacy students, the study by

Cone et al., (2016) found similar results. After a 16-week intervention on explicit critical thinking skills, pharmacy school students increased their evaluation skills. Other studies that examined changes in students' evaluative reasoning skills did not see a statistically significant difference from pretest to posttest scores (Agdas 2013; McGuire, 2010; Phelan, 2012).

Figure 13

Gain in Evaluative Reasoning Skills from Pretest to Posttest



Note. Scores are shown as gain scores (posttest-pretest scores) for the differences in evaluative reasoning skills out of a total possible score of 100. TG = Treatment Group, CG = Control Group. Data from this figure is located in chapter 4, Table 23, page 110.

There was no statistical difference in evaluative reasoning skills between groups; this means though treatment groups TG1 and TG2 showed significant increases from pre to post-tests, when controlling for the covariate, the pretest, there was not a statistically significant difference between treatment group TG1 or TG2 mean posttest scores and the control group's mean posttest scores as analyzed using an ANCOVA. Although teacher participation in both PD1 (a 15 week, structured asynchronous online professional development course by the

Foundation for Critical Thinking) and PD2 (a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates) did increase advanced level high school students' evaluative reasoning skills, the increase was not statistically different from students who were in the control group CG1.

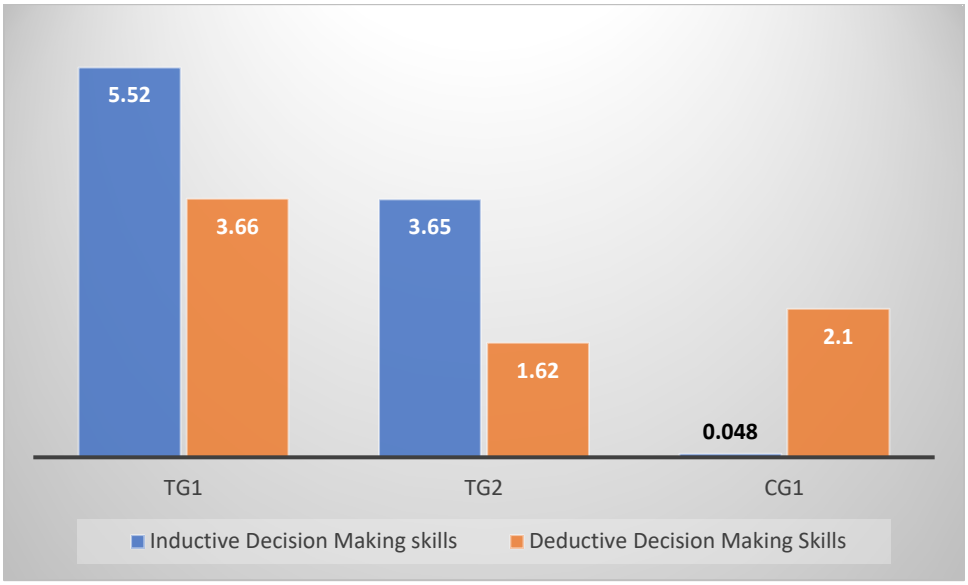
Research Question #5: Summary of Results and Discussion

The fifth question guiding this research was: Does teacher participation in professional development focused on how to infuse critical thinking into teaching impact the decision-making skills of high school students as measured by the induction and deduction subset scores on the California Critical Thinking Skills Test? To assess potential changes in decision-making skills, both deductive and inductive decision-making skills needed to be examined. Inductive decision making consists of decision-making skills based on drawing inferences about what individuals think is true based on data, patterns, experiences, and behaviors (Insight Assessment, 2019). Deductive decision-making skills include decision-making skills that are based on rules, values, policies, procedures, and are logical and clear cut (Insight Assessment, 2019). Individuals need to be able to base the decisions they make on sound judgments and careful evaluation of evidence (Behar-Horenstein & Niu, 2011).

A summary of students' increases in decision-making skills is seen in Figure 14. Participants in treatment groups TG1 and TG2 statistically increased their inductive decision-making skills (Table 30, page 118). The control group’s inductive decision-making skills virtually remained unchanged from pretest to post-test.

Figure 14

Gain in Decision Making Skills from Pretest to Posttest



Note. Scores are shown as gain scores (posttest-pretest scores) for the differences in inductive decision-making skills deductive decision-making skills out of a total possible score of 100. TG = Treatment Group, CG = Control Group. Data from this figure is located in chapter 4, Tables 31 and 32, pages 114-115.

When controlling for the covariate, the pretests, there was a significant difference between the control group CG1 and both treatment group TG1 and treatment group TG2 as well as a difference between treatment group CG1 and the control group CG1. Students developed their inductive decision-making skills better when their teachers participated in the considerably structured online professional development versus participation in the more flexible self-paced video format professional development. One possible reason for this difference among treatment groups could be that the professional development in treatment group TG1 was considerably structured; teachers may have learned and presented information to the students in a step by step manner evenly paced throughout the semester. In contrast,

there was no formal structure in the professional development for treatment group TG2, and teachers may have accessed the professional development in more substantial amounts at intermittent times, which may not have allowed students time to develop the skills needed for developing a measurable increase in inductive decision-making skills. Other studies did not see statistically significant increases in inductive skills (Agdas, 2013; Cone et al., 2016; McGuire, 2010; Phelan, 2012). Other studies that examined changes in inductive reasoning skills did not offer instructor professional development on critical thinking skills as part of their studies. The results of this study suggest when teachers enrolled in PD1, a 15 week, structured asynchronous online professional development course or PD2, a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates, advanced level high school students statistically increase their inductive decision making skills which include recognizing data, patterns, experiences, and behaviors to draw inferences.

Participants in treatment groups TG1 and TG2 statistically increased their deductive decision-making skills (Table 31, page 119). The control group's deductive decision-making skills bordered a statistical increase, and small effect size is interesting to note. This was the only subset in which the control group CG1 approached a statistically significant increase from pretest to posttests. Although the gain score from pretest to post-test is more substantial for the control group CG1 than it is for treatment group TG2 (Figure 14), it is not a statistically significant increase due to the large standard deviation in the control group CG1 deductive decision-making scores (Figure 9, page 117).

Cone et al. (2016) found similar results. After a 16-week intervention on explicit critical thinking skills, pharmacy school students increased their deduction skills. Other studies

that examined changes in students' deductive decision making skills did not see a statistically significant difference from pretest to posttest scores (Agdas 2013; McGuire, 2010; Phelan, 2012).

There was no statistically significant difference in deductive decision-making skills between either of the two treatment groups' posttest scores and the control group CG1 posttest scores when controlling for the covariate, the pretest. When teachers participated in either professional development PD1 or PD2, advanced level high school students' deductive decision-making skills statistically increased, although the increase was not statistically different from advanced level high school students who were in the control group CG1.

Conclusion

This study used a quantitative between group design to examine the relationship between teacher participation in professional development and student critical thinking skills, including overall critical thinking skills, analytical reasoning skills, evaluative skills, inference skills and, decision-making skills. These skills were selected as they help detect students' particular strengths and weaknesses, and the results from the research questions can help educators and administrators address particular aspects of critical thinking skills for future educational opportunities. The sample for the study consisted of 152 student participants from ten class sections at three different school sites assigned to three different groups. The groups consisted of two treatment groups and one control group. The teachers from the treatment groups participated in two semester-long critical thinking professional development protocols that were identical in their content, but unique in their delivery. Both professional developments in this study included the elements of reasoning, universal intellectual standards, and intellectual traits by incorporating discussions, reading, and participating in practical application activities. Teachers learned how to

redesign lessons that fosters explicit critical thinking, apply strategies including Socratic discussion techniques, and use the principles and concepts of critical thinking. The professional development interventions in this study introduced the concept of critical thinking with the goal of helping teachers to understand critical thinking better and infuse it into their course. “It fosters an understanding of how to teach critical thinking skills to students through any subject or discipline, and at any level of instruction” (Foundation for Critical thinking, 2017, para 1).

Treatment group TG1 participated in a structured online course, and treatment group TG2 participated in a self-paced video-based professional development course. The main distinction between the two professional development programs was that the online classroom-based course included faculty mentoring, where teachers had access to a professional development expert and engaged in structured class discussions and collaborations. In contrast, the video-based course participants engaged in informal discussions and were not required to collaborate with others. The students took the California Critical Thinking Test at the beginning of the semester as a pretest and again at the end of the semester as a posttest. The data were analyzed using dependent *t* tests and ANCOVAs. The results supported the hypotheses; there would be a significant increase in student critical thinking skills after teacher participation in critical thinking professional development.

When teachers participated in critical thinking professional development, PD1, which consisted of a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking or PD2, which consisted of an asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates, advanced level high school students statistically increased their overall

critical thinking skills, analytical reasoning skills, inference skills, evaluative reasoning skills, inductive and deductive decision making skills, based on results from dependent *t* tests. Differences between the posttest mean of treatment group TG1 and treatment group TG2 were revealed in both overall critical thinking skills and inductive decision making skills, using ANCOVA to analyze the differences between groups. When teachers enrolled in PD1 (a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking), advanced level high school students showed a statistically significant increase overall critical thinking skills and inductive decision making skills compared to advanced level high school students whose teacher was enrolled in PD2 (a semester-long asynchronous professional development course with the same material as PD1 but with a modular design that had no assignments or due dates as measured by the California Critical Thinking Skills Test (CCTST). Differences between the posttest mean scores of treatment group TG1 and the control group CG1 were found in overall critical thinking, analytical reasoning skills, inference skills, and inductive decision making skills, using ANCOVA to analyze the differences between groups. When teachers enrolled in PD1, (a 15 week, structured asynchronous online professional development course by the Foundation for Critical Thinking) advance level high school students showed a statistically significant increase from a control group in overall critical thinking skills analytical reasoning skills, inference skills, and inductive decision making skills as measured by the California Critical Thinking Skills Test. There were no statistical differences between posttest means of treatment group TG2 and the control group CG1 in any of the subsets measured by the California Critical Thinking Skills Test.

The findings also suggest that teacher participation in PD1, a structured formal online course in critical thinking, is more effective at increasing advanced level high school student

critical thinking skills than self-paced critical thinking professional development, PD2. A possible explanation for the difference in the treatment groups may be due to the regiment of the time requirement. Treatment group TG1 was more regimented, and time and format were set for the semester, which may have resulted in a more evenly spaced application, which may have better facilitated learning for the teachers. Professional development can increase a teacher's readiness and motivation to learn and adopt new teaching approaches (Silm et al., 2017).

Another possible difference in the treatment groups may not have to do with the format of the professional developments but could be due to teacher motivation. Some noted disadvantages to online professional development were lack of social interaction and collaboration, lack of motivation, and lack of accountability (Wynants & Dennis, 2018). Teachers in treatment group TG2 did not have the social interaction of the online class format that treatment group TG1 did, which could have affected the teachers' motivation in applying the material. Online class formats allow teachers to participate actively and be more reflective in their online posts because they have time to reflect and reply when they feel ready to participate (Carey et al., 2008).

Perhaps the school atmosphere and focus were not as conducive to participating and applying the professional development for treatment group TG2. Teachers who can work at their own pace, who understand the number of hours and the time commitment are more deeply engaged in the activities (Cho & Rathbun, 2013). If teachers in treatment group TG2 did not have ample time and resources available to learn and apply the information independently, it may explain a possible reason why the results showed treatment group TG2 differences were not as pronounced as treatment group TG1. School focus and resources could also account for the differences, in that it's possible one school may have had a greater focus in critical thinking than another; therefore the students may have been more receptive and able to apply the critical

thinking skills they were receiving at a faster rate than the students at schools in treatment group TG2 or the control group CG1. A school culture that fosters critical thinking changes the disposition the students have towards critical thinking; it changes the way they see knowledge, how it is assimilated, and the part they play in their personal learning process (Tsui, 2008).

Teachers in the treatment group TG1 may have had higher teacher engagement than treatment group TG2. Although all teachers in the study participated in the study, some may have engaged more in professional development than others. Schools with higher teacher engagement in online professional development outperform other schools in student achievement (Shaha & Ellsworth, 2013). Future research is needed to explore the effect of teacher professional development on students' critical thinking skills.

Recommendations for Further Research

Future research in the area of critical thinking, specifically how professional development can affect students' critical thinking skills, is a necessity. The following future research recommendations are based on both the limitations of this study as well as the results. This quantitative between group research design explored the quantitative effect on student critical thinking skills as the result of teacher professional development but did not address any qualitative questions. Further recommendation includes a study on teachers' views and thoughts about professional development interventions and critical thinking. This study did not examine how teachers used professional development. A future study into how the teachers applied, either implicitly or explicitly, would be of value. A qualitative study including the students, including their observations and experiences within the study, including whether their experiences and understanding of critical thinking and how it affects them changed, would be valuable. Examining if the students thought their pretests affected their posttest results may also

be of value in a future study. This study also did not address students' or teachers' critical thinking dispositions. Critical thinking disposition is the ability to use critical thinking when needed (Facione, 1990). Critical thinking disposition is just as or more important than critical thinking skills themselves (Facione et al., 1996).

The current study included students from similar suburban socioeconomic backgrounds. Expanding a study to more schools of diverse socioeconomic backgrounds could provide a more complete picture of how professional development affects student critical thinking skills. The California Critical Thinking Skills Test is meant for upper-class high school college preparatory/honors or Advanced Placement students or above, but a future study could use another assessment tool to explore the effect of critical thinking professional development on lower-class high school students or students in lower-level courses. Furthermore, expanding the study to other populations, including either a quantitative or a qualitative study to community colleges and universities, could yield interesting results. The use of multiple measures, including other critical thinking assessments, surveys, etc. to better detect differences in critical thinking skills, could help evaluate the effectiveness of teacher professional development on student critical thinking skills.

This study contained a quantitative between group design, which was a limitation for this study; a future study should include random assignment of participants. A future study that included an experimental design could be beneficial. A random experimental between-group design using a control group and intervention group design is the most rigorous and robust experimental design (Creswell, 2015).

Students with higher critical thinking skills have higher achievement (Ghanizadeh, 2017). A future study could include examining students' grades over the course of the semester in a

similar study. The study could also include other assessments, such as how students' problem-solving strategies change over the semester. When students can think critically using skills like analyzing and critiquing information at a high level, they can engage in more in-depth and more sophisticated problem-solving strategies, which helps them to be more efficient in their academic studies (Ghanizadeh, 2017; Ramsey & Baethe, 2013). Another possibility could be to follow these students and examine if there is a long-term effect on their critical thinking skills. Tiwari et al. (2006) showed that the critical thinking skills learned in one class could have a marked effect on the students' long-term critical thinking skills.

Implications for Professional Practice

To create effective decision-makers, developing critical thinking skills is of the utmost importance (Wang & Zheng, 2016). This study explored the effect of teacher professional development on students' critical thinking skills. Both treatment groups, TG1 and TG2, saw students' overall critical thinking skills, analytical thinking skills, inference skills, evaluative reasoning skills, and inductive decision-making skills increase after teacher participation in critical thinking professional development. Although treatment group one saw greater gains, having teachers participate in a semester-long considerably structured expensive professional development may not be an option for many schools and many teachers. The more flexible, less expensive, self-paced, video-based professional development may be more practical.

The results of this study support other professional development studies in that long term, flexible, high quality, content-focused professional development can increase student gains. Ongoing professional development that teachers can access daily and integrate into their schedule is much more powerful than single-day professional development (Carey et al., 2008). Online professional development that includes peer coaching and lesson planning while

addressing learning methods of students, deepens teachers' content knowledge, and includes active learning is effective (Carey et al., 2008; Sparks, 2002). Online professional development is unique in that it can fit into teachers' busy schedules and provide resources not available at the local level, provide teachers access to experts, provide consistent support, and cost much less than in person professional development (Dede et al., 2005). Effective professional development that leads to student gains includes built in time for teachers to reflect, receive input, and make changes to their current teaching practice (Darling-Hammond et al., 2017).

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Appendix A: Quantitative Teacher Informed Consent

INFORMED CONSENT FORM

A. PURPOSE AND BACKGROUND

Jennifer McAdam M.S., doctoral student in Educational Leadership at Northwest Nazarene University is conducting a research study related to critical thinking skills of students after teacher participation in professional development. I hope to discover how professional development can help increase student critical thinking skills.

You are being asked to participate in this study because you are a healthy volunteer, over the age of 18.

B. PROCEDURES

If you agree to be in the study, the following will occur:

1. You will be asked to sign an Informed Consent Form, volunteering to participate in the study.

2. You will be asked to participate in a professional development program with the following criteria
    - Teachers agree to participate in a minimum of 20 hours of professional development over one semester
    - Teachers agree to access professional development course materials at least once a week
    - Teachers agree to incorporate critical thinking skills into lectures, quizzes, tests, projects/labs or other assessments on a weekly basis
    - Teachers agree to take a monthly survey attesting to their participation and use of critical thinking skills in their instructions
    - Teachers agree to refrain from discussing the professional development with their students as to not unduly interfere with pretest or posttest student data

C. RISKS/DISCOMFORTS

1. Some of the questions may make you uncomfortable or upset, but you are free to decline to answer any questions you do not wish to answer or to stop participation at any time.

2. For this research project, the researchers are requesting demographic information. The researchers will make every effort to protect your confidentiality. However, if you are uncomfortable answering any of these questions, you may leave them blank.

3. Confidentiality: Participation in research may involve a loss of privacy; however, your records will be handled as confidentially as possible. No individual identities will be used in any reports or publications that may result from this study. All data from notes,

tests, and surveys will be kept in a locked file cabinet in the Department and the key to the cabinet will be kept in a separate location. In compliance with the Federal wide Assurance Code, data from this study will be kept for three years, after which all data from the study will be destroyed (45 CFR 46.117).

4. Only the primary researcher and the research supervisor will be privy to data from this study. As researchers, both parties are bound to keep data as secure and confidential as possible.

D. BENEFITS

There will be no direct benefit to you from participating in this study. However, the information your child provides may help educators understand how a teachers critical thinking level affects student's critical thinking levels.

E. PAYMENTS

There are no payments for participating in this study.

F. QUESTIONS

If you have questions or concerns about participating in this study, you should first talk with the researcher can be contacted via email at jmcadam@nnu.edu , via telephone at 949-597-0646. If for some reason you do not wish to do this, you may contact Dr. Lynn Bohecker, Doctoral Committee Chair at Northwest Nazarene University, via email at lbohecker@nnu.edu, via telephone at 208-467-8184, or by writing: 623 university Drive, Nampa, Idaho, 83686.

G. CONSENT

You will be given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. Your decision as to whether or not to participate in this study will have no influence on your present or future status as a student at your College.

I give my consent to participate in this study:

_____ _____

Signature of Study Participant **Date**

THE NORTHWEST NAZARENE UNIVERSITY INSTUITIONAL REVIEW BOARD HAS REVIEWED THIS PROJECT FOR THE PROTECTION OF HUMAN PARTICIPANTS IN RESEARCH.

Appendix B: Quantitative Informed Consent Parent/Guardian

INFORMED CONSENT FORM- MINOR

H. PURPOSE AND BACKGROUND

Jennifer McAdam M.S., doctoral student in Educational Leadership at Northwest Nazarene University is conducting a research study related to critical thinking skills of teachers and students after participating in online professional development. I hope to discover how online professional development can help increase teachers and students critical thinking skills.

Consent for Minor to Participate

Student's name:_____

Parent's/Guardian's name:_____

I. PROCEDURES

I understand that the general purposes of the research are to investigate the level of critical thinking skills before and after online teacher professional development and I understand that my child's participation will involve taking a pre and posttest. The approximate total time of my child's involvement will be not more than 100 minutes.

If you agree to be in the study, the following will occur:

1. You will be asked to sign an Informed Consent Form, allowing your student to participate in the study.

2. Your student will take a pre-test at the beginning of the semester and a post-test at the end of the semester. Each test lasts approximately 45-50 minutes each for a total of 90-100 minutes. Their response(s) will help to provide information about how online professional development can help increase student critical thinking skills.

3. If your child is uncomfortable with any questions on the test, your child may skip those questions and may choose to end the test at any time.

These procedures will be completed in a classroom, in the library or at a location mutually decided upon by the participant and principal investigator and will take a total of about 45-50 minutes each.

J. RISKS/DISCOMFORTS

1. If any of the questions make your child uncomfortable or upset, he or she is free to

decline to answer any questions your child does not wish to answer or to stop participation at any time.

2. For this research project, the researchers are requesting demographic information. The researchers will make every effort to protect your child's confidentiality. However, if your child is uncomfortable answering any of these questions, they may leave them blank.

3. Confidentiality: Participation in research may involve a loss of privacy; however, records will be handled as confidentially as possible. No individual identities will be used in any reports or publications that may result from this study. All data from notes, surveys and tests, will be kept in a locked file cabinet and the key to the cabinet will be kept in a separate location. In compliance with the Federal wide Assurance Code, data from this study will be kept for three years, after which all data from the study will be destroyed (45 CFR 46.117).

4. Only the primary researcher and the research supervisor will be privy to data from this study. As researchers, both parties are bound to keep data as secure and confidential as possible.

K. BENEFITS

There will be no direct benefit to your child from participating in this study. However, the information your child provides may help educators understand how a teachers critical thinking level affects students critical thinking levels.

L. PAYMENTS

There are no payments for participating in this study.

M. QUESTIONS

If you have questions or concerns about participating in this study, you should first talk with the researcher can be contacted via email at jmcadam@nnu.edu , via telephone at 949-597-0646. If for some reason you do not wish to do this, you may contact Dr. Lynn Bohecker, Doctoral Committee Chair at Northwest Nazarene University, via email at lbohecker@nnu.edu, via telephone at 208-467-8184, or by writing: 623 University Drive, Nampa, Idaho, 83686.

N. CONSENT

You will be given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. Your decision as to whether or not to participate in this study will have no influence on your present or future status as a student at your school.

I authorize Jennifer McAdam, doctoral student, Northwest Nazarene University, Nampa, ID, and/or any designated research assistants to gather information from my child on the topic of the link between critical thinking skills and online professional development.

My child and I have been assured that my child may refuse to discuss any matters that cause discomfort or that my child might experience as an unwanted invasion of privacy. I am aware that my child may choose not to answer any questions that my child finds uncomfortable.

I understand that my child's participation is voluntary and that my child may refuse to participate or discontinue participation at any time without penalty or loss of benefits to which my child may be otherwise entitled.

This study is unlikely to cause my child distress. However, I understand that if, after participation, my child experiences any undue anxiety or stress or has questions about the research or his/her rights as a participant that may have been provoked by the experience Jennifer McAdam will be available for consultation, and will also be available to provide direction regarding medical assistance in the unlikely event of injury incurred during participation in the research.

I understand that confidentiality of research results will be maintained by the researcher. No individual results will be released without my written consent as the parent or guardian of the particular child.

I give my consent for my child to participate in this study:

_____ _____

Signature of Parent or Guardian **Date**

THE NORTHWEST NAZARENE UNIVERSITY INSTUITIONAL REVIEW BOARD HAS REVIEWED THIS PROJECT FOR THE PROTECTION OF HUMAN PARTICIPANTS IN RESEARCH.

Appendix C: Parent/Student Invite Letter

Date _____

Dear _____,

My name is Jennifer McAdam. I am a doctoral student at Northwest Nazarene University specializing in Educational Leadership. I am currently doing a research study on critical thinking skills in students and teachers. The purpose of the study is to explore if online professional development has the ability to effectively train teachers to infuse essential critical thinking skills into their instruction and increase their students critical thinking skills. The administration has approved this study and your child's teacher has agreed to participate. The students in your child's class, including your child, will be taking a critical thinking skills assessment as a pre-test at the beginning of the semester and again as a post test at the end of the semester.

If you are willing to participate, please contact me by August 8th, 2019 at jmcadam@nnu.edu. Or, you can complete the information below and return this form to your teacher or bring it to the front desk at your school.

The only time commitment required is a 45-minute 40-question multiple choice test, that will be taken on a computer at the beginning of the semester and again at the end of the semester.

By participating you would be making a valuable contribution to the study. You would also be helping me to achieve my goal of encouraging student success.

Thank you so much for your time.
With warm regards,
Jennifer McAdam

Participant Response
I accept the offer for my child to participate in the study.

_____
Participant name

If you have agreed to allow your student to participate in this study, please fill out the attached consent form. This form can be returned to your student's teacher, the front desk or to the researcher, Jennifer McAdam.

QUESTIONS: If you have questions or concerns about participating in this study, you should first talk with the researcher can be contacted via email at jmcadam@nnu.edu, via telephone at 949-597-0646. If for some reason you do not wish to do this, you may contact Dr. Lynn Bohecker, Doctoral Committee Chair at Northwest Nazarene University, via email at

lbohecker@nnu.edu, via telephone at 208-467-8184, or by writing: 623 University Drive, Nampa, Idaho, 83686.

Appendix D: Student Assent Script

ASSENT SCRIPT

Project Title: An Investigation of the Relationship Between Critical Thinking Skills and
Principal Investigator: Jennifer McAdam; Doctoral Student;
Supported by: Northwest Nazarene University

Hi, my name is Jennifer. If you have any questions about what I am telling you, you can ask me at any time.

I want to tell you about a research study we are doing. In this study, we want to find out more about how students like you use critical thinking skills.

You are being asked to be in this because you are in 11-12 grade.

If it is okay with you, I will ask to take a test on a computer this will take about 45-50 minutes.

If you get too tired or if you would like to stop, just tell me and we will stop.

You do not have to be in this study. It is totally up to you. You can say yes now and still change your mind later. All you have to do is tell me. No one will be mad at you if you change your mind. No one will be upset if you change your mind.

Your parents/people taking care of you said it is okay for you to be in this study. If you have questions for me or for your parents/people who care for you, you can ask them now or later.

Do you understand what I am saying and are you willing to take this test which includes questions about how you use critical thinking skills?

At no time will your information or responses be seen by anyone but the researcher. All material will be kept anonymous and stored in a password protected computer.

End of verbal script.

To be completed by person obtaining verbal assent from the participant:

Child's/Participant's response**:** ☐Yes ☐No

Check which applies below:

☐The child/participant is capable of understanding the study

☐The child/participant is not capable of understanding the study

_____

Child's/Participant's Name (printed)

_____ _____

Name (printed) and Signature of Person Obtaining Consent Date

QUESTIONS: If you have questions or concerns about participating in this study, you should first talk with the researcher can be contacted via email at jmcadam@nnu.edu, via telephone at 949-597-0646. If for some reason you do not wish to do this, you may contact Dr. Lynn Bohecker, Doctoral Committee Chair at Northwest Nazarene University, via email at lbohecker@nnu.edu, via telephone at 208-467-8184, or by writing: 623 University Drive, Nampa, Idaho, 83686.

Appendix E: Teacher Invite Email
TEACHER PARTICIPANT INVITE LETTER AND EMAIL

Date _____

Dear _____,

My name is Jennifer McAdam. I am a doctoral student at Northwest Nazarene University specializing in Educational Leadership. I am currently doing a research study on critical thinking skills in students. The purpose of the study is to explore if professional development has the ability to effectively train teachers to infuse essential critical thinking skills into their instruction and increase their students critical thinking skills.

There will be intervention groups, receiving professional development and control groups not receiving professional development.

The criteria for professional development commitment are as follows:

- Teachers will participate in a minimum of 20 hours of professional development over one semester
- Teachers agree to access professional development course materials at least once a week
- Teachers agree to incorporate critical thinking skills into lectures, quizzes, tests, projects/labs or other assessments on a weekly basis
- Teachers agree to take a monthly survey attesting to their participation and use of critical thinking skills in their instructions

Teachers selected for the study will be randomly assigned to an intervention group to participate in a professional development intervention or assigned to the control group who will not participate in a professional development intervention.

Your students in your class will be taking a critical thinking skills assessment as a pre-test in the beginning of the semester and again as a post test at the end of the semester.

If you are willing to participate, please contact me by August 8th, 2019 at jmcadam@nnu.edu. Or, you can complete the information below and return this form to your teacher or bring it to the front desk at your school.

By participating, you would be making a valuable contribution to the study. You would also be helping me to achieve my goal of encouraging student success at NNU.

Thank you so much for your time.
With warm regards,
Jennifer McAdam

Participant Response

I accept the offer to participate in the study.

_____

Participant name

QUESTIONS: If you have questions or concerns about participating in this study, you should first talk with the researcher can be contacted via email at jmcadam@nnu.edu, via telephone at 949-597-0646. If for some reason you do not wish to do this, you may contact Dr. Lynn Bohecker, Doctoral Committee Chair at Northwest Nazarene University, via email at lbohecker@nnu.edu, via telephone at 208-467-8184, or by writing: 623 University Drive, Nampa, Idaho, 83686.

Appendix F: Demographic Questionnaire Student

DEMOGRAPHIC QUESTIONNAIRE STUDENT

Participant's Name: _____

Check one:
Male_____ Female _____ Other_____

Age (in years) _____

Date of Birth (optional) Month ___ Day___ Year_____

High School GPA (check one):

3.5-4.0 _____

3.0-3.49_____

2.5-2.99____

2.0-2.49____

Under 2.0____

Are you (check one):

White (1) _____

African-American (2) _____

American Indian or Alaskan Native (3) _____

Asian (4) _____

Native Hawaiian or another Pacific islander (5) _____

Multiple races (6) _____

Other (please specify) (7) _____

Appendix G: Teacher Demographic Questionnaire

DEMOGRAPHIC QUESTIONNAIRE ADULT

Participant's Name: _____

Check one:
Male_____ Female _____ Other_____

Age (in years) _____

Date of Birth (optional) Month ___ Day___ Year_____

Native Language (check one):

English (1) ____

Spanish (2) ____

Other (3) ____

Marital Status (check one):

Single, Never Married (1) _____

Divorced/Separated (2) ____

Married (3) ____

Prefer not to answer (4) ____

Highest level of education (check one):

Bachelor's degree (1) ____

Graduate degree (2) ____

Number of years teaching experience:
Less than 1 _____

1-2_____

3-4_____

5-6_____

7-8_____

9-10_____

11+_____

Are you (check one):

White (1) _____

African-American (2) _____

American Indian or Alaskan Native (3) _____

Asian (4) _____

Native Hawaiian or another Pacific islander (5) _____

From multiple races (6) _____

Some other race (please specify) (7) _____

Appendix H: Site Permission Letter

[redacted]

February 12, 2019

[redacted]

RE: Research Proposal Site Access for Mrs. Jennifer McAdam

Dear IRB members:

This letter is to inform the IRB that Administration at [redacted] has reviewed the proposed dissertation research plan including subjects, intervention, assessment procedures, proposed data and collection procedures, data analysis, and purpose of the study. Mrs. McAdam has permission to conduct her research at the site of [redacted] with students and staff of [redacted] The authorization dates for this research are August 2019-May 2021.

Respectfully,

[redacted]

[redacted]

Appendix I: National Institute for Health Certification

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **Jennifer McAdam** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 01/18/2018.

Certification Number: 2604268.

Appendix J: Teacher Professional Development Survey

During the last month, how frequently have you participated in the following activities related to the professional development course on infusing critical thinking skills? For any activity in which you participated, indicate the extent you believe the activity has improved your classroom teaching.

For the purpose of this study, assessments include tests, quizzes, labs, projects or other assignments

General Questions:

1. I competed this month's professional development course requirements/expectations: yes/no

2. How frequently did you access the professional development material?
   Never Daily At least once a week 2 to 3 times a month Once a month

3. The lessons I learned in my critical thinking course informed/influenced my lesson planning
   Never Daily At least once a week 2 to 3 times a month Once a month

Analytical reasoning skills
These skills allow students to identify assumptions, claims and reasons to examine how these assumptions interact in the formation of arguments. Analytical reasoning skills are used to gather information from spoken language, diagrams, graphs, charts, and documents. These skills help students identify the elements of a situation and determine how those elements interact.

4. I incorporated analytical reasoning skills into my assessments or lectures
   Never Daily At least once a week 2 to 3 times a month Once a month

Inference skills
Inference skills enable students to draw conclusions from reasons and evidence. These skills are used when making thoughtful suggestions and hypothesis and help students to determine the consequences of a given set of facts or conditions.

5. I incorporated inference skills into my assessments or lectures
   Never Daily At least once a week 2 to 3 times a month Once a month

Evaluative reasoning skills
These skills enable students to assess the credibility of sources of information and the claims they make. These skills are used to determine the strengths and weaknesses of arguments and enable students to judge the quality of analyses, explanations, reasons, and decisions.

6. I incorporated evaluative reasoning skills into my assessments or lectures

Never Daily At least once a week 2 to 3 times a month Once a month

Decision making skills

7. I incorporated decision making skills into my assessments or lectures
   Never Daily At least once a week 2 to 3 times a month Once a month

Appendix K: Bloom's Taxonomy Figure Permission