THE CHALLENGE OF CHANGE:
IMPLEMENTING CRITICAL THINKING INSTRUCTION
IN THE CULTURE OF INDEPENDENT, PRIVATE SCHOOLS

by
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A dissertation submitted to Johns Hopkins University in conformity with the requirements for the degree of Doctor of Education

Baltimore, MD

August 2017
Abstract

Among the 21st century skills promoted by educational reform initiatives is critical thinking, an advanced cognitive ability required to solve complex problems in real-world contexts. In spite of national reform efforts, critical thinking skills remain underdeveloped among many high school graduates. Challenges unique to autonomous, independent, private schools often hinder teachers’ adoption of reform-oriented, critical thinking instructional practices. In the private school sector, teacher efficacy, pedagogical beliefs, collaboration, professional development, and evaluation systems all greatly influence the teachers’ adoption of reform-oriented practices. According to the results of a needs assessment study performed at a secondary, independent school, the pedagogical beliefs and professional development variables were selected as targets of an intervention designed to enhance the teachers’ adoption of critical thinking instructional practices. The intervention, implemented within the school’s Science Department, incorporated components recommended by the professional development and critical thinking literature in order to positively influence the teacher participants’ knowledge, pedagogical beliefs, and adoption of critical thinking instructional practices. A program evaluation revealed that the intervention only produced a moderate impact on the participants’ knowledge and pedagogical beliefs but a significant impact on the participants’ adoption of critical thinking practices. Overall, the program components, including the mentoring sessions, professional development workshops, peer observations, observation feedback, and peer collaborations, supported the participants’ professional growth in critical thinking pedagogy.

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Dedication

This dissertation is dedicated to my precious sons, Michael and Andrew, for inspiring me to achieve my goals. May your mother’s example inspire you to be lifelong learners and to never give up on your dreams.
Acknowledgements

I would like to acknowledge the many individuals whose tremendous support and guidance contributed to my successful completion of this doctoral program.

First, my deepest gratitude is extended to my dissertation adviser, Dr. Karen Karp, for her support, patience, and guidance. Dr. Karp’s rigorous feedback consistently challenged me to perform to my highest level, and for that, I am forever grateful. In addition, I would like to extend my deepest thanks to my dissertation committee members, Dr. Wendy Drexler and Dr. Gail Donahue, for devoting their time and expertise to this project. I would like to extend a special thank you to Dr. Gail Donahue, whose example and passion for education inspired me to pursue this doctoral degree. Also, I would like to express my gratitude to Dr. Chris Sessums, whose mentorship provided me with the support and encouragement needed to successfully complete my first semester as a doctoral student.

In addition, I would like to extend a heartfelt thank you to my colleagues in the 2014 cohort with whom I embarked on this academic journey. In particular, I am deeply grateful for my colleagues in “Team A” – Christine Brookbank, Lisa Devall-Martin, Lauren Fagel, Caitlin Gosnell, and Cynthia Webb – whose support and friendship motivated me to persevere and succeed in this program. I would like to extend a very special thank you to my dear friend, Christine Brookbank. I can’t imagine traversing this program without Christine’s friendship and encouragement. I look forward to the continued growth of our life-long friendship that commenced at our first doctoral orientation.
I would also like to express my deepest gratitude to my work colleagues and school leaders for their unwavering support of my educational endeavors. I am continually in awe of the talent and enthusiasm demonstrated by my colleagues in the Science Department. They motivate me to be the best teacher and leader I can be and to continually grow in my professional practice. I am truly blessed to work with such inspiring and passionate individuals on a daily basis.

Finally, I would like to thank my family members, my biggest cheerleaders, for their unconditional love and support. I am truly blessed to have been raised by parents whose example motivated and inspired me to pursue my dreams. Their unwavering support, love, and guidance provided me with the confidence to embark on this journey and the inspiration to reach for the stars. Also, I would like to thank my children, Michael and Andrew, for their love and patience while I worked tirelessly to complete this program. You inspire me to be the best person and parent I can be. I can only hope that I have, in turn, inspired you to always believe in yourself and to never give up on your dreams. And finally, I would like to extend my deepest thank you to my husband and best friend, Mark. I cannot imagine embarking on this journey without you by my side. Your faith, hope, and love inspire me to be the best version of myself, and for that, I am forever grateful.
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Executive Summary

In recent years, educational reform efforts increasingly emphasize the importance of preparing students with the 21st century skills needed to succeed in today’s rapidly evolving world (Common Core, Undated; National Commission on Teaching and America’s Future, 1996). Among the skills deemed essential for success in the 21st century is critical thinking, a higher-order thinking skill that permits complex problem-solving through the application of advanced cognitive abilities (Garet, Porter, Desimone, Birman, & Yoon, 2001; Partnership for 21st Century Skills, 2008). However, in spite of reform efforts that increasingly target 21st century skill development, critical thinking skills remain underdeveloped among high school graduates in the United States (Pinkney & Shaughnessy, 2013).

An Overview of the Problem of Practice

In the private, independent school context, numerous factors contribute to the underdevelopment of students’ critical thinking skills. First, the need for private schools to maintain their competitive edge in the private school market influences decision-making processes that ultimately impact student outcomes. An increased emphasis on external incentives and policies that meet the demands of stakeholders often diminishes the emphasis placed on internal processes essential for ensuring the school’s academic excellence over time (Berends, Goldring, Stein, & Cravens, 2010). Second, the autonomous nature of most independent schools influences educational decision-making processes and thus student outcomes in these institutions. While their public school counterparts are encouraged to adopt reform initiatives recommended by experts in the field of education, autonomous private schools have the flexibility to implement policies
that may or may not adhere to current research in educational reform (Lubienski, Lubienski, & Crane, 2008a).

Among the internal processes that receive inadequate emphasis in many private schools striving to meet the demands of external stakeholders is classroom instruction. Recent educational research supports adherence to student-centered instructional approaches that align with cognitive or constructivist learning theories in order to cultivate students’ critical thinking skills (Abrami, Bernard, Borokhovski, Waddington, Wade, & Persson, 2015; Berends et al., 2010; Ertmer & Newby, 1993; Garet et al., 2001). According to cognitive learning perspectives, students develop advanced critical thinking skills when they progress to the formal operational stage, or stage 4, of cognition (Piaget, 1970; Pinkney & Shaughnessy, 2013). Similarly, according to Bloom’s Taxonomy (Bloom, 1956), students develop higher-order thinking skills as they advance through the cognitive rungs of a hierarchical ladder. According to constructivist and sociocultural perspectives, students develop critical thinking skills when encouraged to work collaboratively within their zone of proximal development to solve authentic, complex problems situated in real-world contexts (Gee, 2008; Resnick, 1987; Vygotsky, 1978). However, while extensive research supports the use of student-centered instructional practices that align with cognitive and constructivist learning theories, teacher-centered instructional practices persist in secondary, private school settings (Dosen, Gibbs, Guerrero, & McDevitt, 2004; Pinkney & Shaughnessy, 2013). When compared to student-centered instructional practices, teacher-centered practices, such as lecture, inadequately support students’ development of critical thinking skills (Abrami et al., 2015; Elder & Paul, 2008; Ertmer & Newby, 1993).
In autonomous, private school cultures, there exist multiple teacher- and school-level factors that influence the teachers’ adoption of student-centered, critical thinking instructional practices. Among these factors are teacher self-efficacy and collaboration, both of which are positively associated with a teacher’s adoption of innovative practices. There exists a reciprocal relationship between teacher self-efficacy and quality instruction, such that positive self-efficacy beliefs not only promote quality instruction, but quality instruction also enhances teacher self-efficacy (Holzberger, Philipp, & Kunter, 2013). Similarly, the cohesiveness of faculty collegial networks is positively correlated with the network members’ adoption of innovative instructional practices (Bidwell & Yasumoto, 1999; Chong & Kong, 2012). When faculty networks support the implementation of quality instructional practices, they, in turn, enhance teachers’ self-efficacy beliefs (Holzberger et al., 2013). However, in autonomous, independent school cultures, the isolation of faculty members within departmental silos hinders cross-collaboration and thus adoption of critical thinking instructional practices (Chong & Kong, 2012; Krishnan, 2009). Furthermore, the cohesiveness of existing collegial networks weakens in autonomous school cultures subject to increased pressure for reform (Bidwell & Dreeben, 2003).

In addition to teacher self-efficacy and collaboration, pedagogical beliefs significantly influence a teacher’s adoption of reform-oriented instructional practices (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Smith, 2000). When challenged by reform efforts, the adherence to traditional, teacher-centered pedagogical beliefs hinders a teacher’s successful transition to student-centered, reform-oriented practices that cultivate students’ critical thinking (Smith, 2000). Furthermore, a teacher’s
use of technological resources reflects his espoused pedagogical beliefs; teachers with traditional, teacher-centered beliefs integrate technology in a teacher-centered learning environment that inadequately supports students’ cognitive development (Ertmer et al., 2012). Therefore, in autonomous, independent schools, the persistence of teacher-centered instructional practices may reflect the ongoing adherence to traditional, teacher-centered pedagogical beliefs (Ertmer et al., 2012; Lubienski et al., 2008a).

Both professional development and teacher evaluation programs greatly influence teachers’ pedagogical beliefs and adoption of critical thinking instructional practices. Effective professional development and evaluation frameworks provide teachers with ongoing support and guidance to facilitate their effective adoption of reform-oriented, student-centered practices (Donaldson, 2013; Garet et al., 2001). However, due in part to the lack of available research on effective professional development frameworks (Garet et al., 2001), many schools implement programs that fail to produce improvement in either teacher practice or student achievement (Harris & Sass, 2001). In addition, professional development programs that educate teachers in reform-oriented practices often inadequately promote the consistent and effective transfer of these learned strategies to the classroom context (Belvis, Pineda, Armengol, & Moreno, 2013). Furthermore, the subjective evaluation feedback commonly provided in autonomous school cultures inadequately supports teachers in their professional growth and adoption of critical thinking instructional practices (Donaldson, 2013; Master, 2014; Sharkey & Goldhaber, 2008). Therefore, teacher self-efficacy, collaboration, pedagogical beliefs, professional development, and evaluation programs represent factors that influence
teachers’ adoption of critical thinking instructional practices in the private, independent school context.

Needs Assessment Study

In order to examine the extent to which the aforementioned school- and teacher-level factors support the adoption of critical thinking instructional practices, the researcher performed a needs assessment study within the context of an independent, Catholic school (Macek, 2015). The prestigious school, serving girls in grades 6 through 12, is a member of a larger consortium of accredited, independent schools consisting of more than 45,000 students¹. The selected school provided an ideal setting for the study; it is an independent school in the early stages of a reform initiative focused on improving the students’ development of 21st century skills, including critical thinking. To support teachers in the reform process, the school’s administration initiated a pilot professional development program during the 2013-2014 school year. The reform program required teachers to re-think and replace their traditional, teacher-centered pedagogy with innovative, student-centered strategies more conducive to 21st century skill development. However, in spite of this primary objective of the reform program, traditional, teacher-centered practices persist at the school (Macek, 2015).

The study methodology included the administration of quantitative, Likert-style surveys to students and teachers in the high school core subject areas of science, mathematics, social studies, and English. The teacher survey investigated the extent to which the independent variables support or hinder the dependent variable: teacher adoption of critical thinking instructional practices. The independent variables assessed in the study included: teacher self- and collective efficacy beliefs, teacher collaboration,
pedagogical beliefs, professional development, and teacher evaluations. The student survey measured the frequency with which teachers in the core subject areas implement strategies that support students’ critical thinking. Statistical analyses performed on the teacher surveys revealed that pedagogical beliefs, professional development, and teacher evaluations often do not support teachers’ adoption of critical thinking instructional practices. Statistical analyses performed on the student surveys confirmed the persistence of teacher-centered practices in all four of the assessed subject areas (Macek, 2015).

**Intervention and Rationale**

According to the needs assessment study findings, the school’s professional development program provided teachers with inadequate support in the area of critical thinking instruction (Macek, 2015). Yet, as is evidenced by its adoption of a 21st century reform initiative, the school clearly values 21st century education and the professional growth of its employees. Therefore, the researcher targeted the professional development variable to design an intervention that would more effectively foster the teachers’ professional growth and adoption of critical thinking instructional practices.

In order to promote the teacher participants’ adoption of critical thinking instructional practices, the researcher designed an intervention that reflects the recommendations of current research in both professional development and in critical thinking instruction. According to the literature, professional development programs that provide ongoing teacher support (Desimone, Porter, Garet, Yoon, & Birman, 2002; Donaldson, 2013), encourage teacher collaboration (Bidwell & Yasumoto, 1999; Chong & Kong, 2012), and model student-centered strategies (Garet et al., 2001) encourage teachers’ adoption of the promoted pedagogical practices. Therefore, using the cognitive
apprenticeship model (Brown, Collins, & Duguid, 1989) as a guide, the researcher designed an intervention framework that integrated current findings from the professional development literature to promote the participants’ adoption of critical thinking instruction. In particular, the intervention would provide ample opportunities for the teacher participants to observe and practice critical thinking instructional strategies such as problem-based and inquiry-based learning (Marshall & Horton, 2011; Sungur & Tekkaya, 2006; Wheeler, Kelly, & Gale, 2005). In addition, the intervention would promote ongoing collaboration among the participants in order to enhance their adoption of the critical thinking practices (Bidwell & Yasumoto, 1999; Chong & Kong, 2012). Finally, by encouraging teacher reflection, the intervention would support the successful transfer of the learned strategies to the classroom context (Duzor, 2011).

In conjunction with the professional development literature (Desimone et al., 2002; Garet et al., 2001; Guskey, 2014), Collins, Brown, and Newman’s (1989) four cognitive dimensions – content, method, sequence, and sociology – provided a framework for the professional development intervention. During the content dimension, the teacher participants would develop knowledge of critical thinking instructional strategies and how to adapt them to their specific subject area. During the method dimension, the participants would experience professional growth via modeling and coaching by the researcher, by reflecting on their instructional practice, and by applying their developing knowledge of critical thinking to their classroom instruction. During the sequence dimension, the participants would further develop their skills and expertise in critical thinking instruction through the performance of authentic problem-solving tasks of increasing complexity. Finally, during the sociology dimension, the researcher would
guide the teacher participants’ towards critical thinking expertise by encouraging their active collaboration with one another and their application of the learned critical thinking strategies within their authentic classroom context. Ultimately, through the sequential application of Collins et al.’s (1989) four cognitive dimensions to the professional development framework, the researcher would guide the participants towards critical thinking expertise by enculturating them in an authentic learning environment that would positively influence their belief system, knowledge acquisition, and instructional practice (Collins et al., 1989; Stewart & Lagowski, 2003).

**Intervention Design**

Over a period of six months, the researcher delivered a combination of theory-driven professional development activities to the teacher participants in order to increase their adoption of student-centered instructional practices that ultimately improve the students’ critical thinking development. The effective implementation of the intervention components was expected to promote change in the mediating variables of knowledge and pedagogical beliefs which, in turn, would influence the teachers’ level of adoption of student-centered practices (outcome variable). Thirteen teachers from the Science Department at the independent, Catholic school (ICS) volunteered to participate in the intervention. The 13 participants self-selected to one of two groups: a treatment group or a control group. Members of the treatment group (eight total) participated in the components of the intervention, to include: four professional development workshops, four mentoring sessions with the researcher, and two peer observations. The control group members (five total) conducted business as usual during the six-month intervention period.
Over a six-month time period, the eight treatment group members participated in four, 90-minute professional development workshops during which they engaged in activities that increased their knowledge of instructional strategies that foster students’ critical thinking development within secondary, science classrooms. During each of the professional development workshops, the researcher enhanced the participants’ pedagogical knowledge via PowerPoint presentations that provided an overview of critical thinking components and instructional strategies. In addition, during the workshops, the participants viewed video lessons that modeled the promoted critical thinking instructional strategies, in particular problem-based and inquiry-based learning (Marshall & Horton, 2011; Sungur & Tekkaya, 2006; Wheeler et al., 2005). Also, the participants collaboratively reflected on their professional practice, discussed strategies for applying the learned instructional approaches to their classroom context, and designed lessons and student assignments that promoted critical thinking development.

In addition, in-between the professional development workshops, the treatment group members engaged in four mentoring sessions with the researcher. During each mentoring session, attended by one or two treatment group members, the researcher provided additional personalized support to the participants. In particular, because the treatment group participants were observed informally at two time-points by a peer in the program and formally at two time-points by the researcher, the mentoring sessions provided time for the participants to collaboratively reflect on the observation feedback and to brainstorm strategies for improving their professional practice. During the sessions, the researcher served as a mentor to guide the participants’ expertise development and to facilitate their professional growth.
Program Evaluation

The researcher performed a program evaluation in order to measure the intervention’s effectiveness in achieving the desired outcome: the teachers’ increased adoption of student-centered instructional practices that cultivate critical thinking skills. In order to have practical significance, the intervention would need to attain an effect size with a minimum magnitude of 0.42 (Boston & Smith, 2009; Fulmer & Liang, 2012). Using a pretest-posttest control group design (Shadish, Cook, & Campbell, 2002), quantitative and qualitative data were collected pre- and post-intervention to indicate the impact of the intervention on the participants’ knowledge (mediating variable), pedagogical beliefs (moderating variable), and adoption of critical thinking instructional practices (outcome variable).

A variety of data were collected and analyzed in order to determine the intervention’s effectiveness in producing the desired outcomes. First, a survey with questions adapted from existing instruments (Isikoglu, Basturk, & Karaca, 2009; Stapleton, 2011) was administered to both the treatment and control group participants at pre- and post-intervention. The quantitative, Likert-scale survey questions served to indicate any change in the participants’ pedagogical beliefs and knowledge of critical thinking instruction following the intervention. In addition, responses to an open-ended survey question served to indicate any change in the participants’ critical thinking knowledge over time.

Furthermore, once before and once following the completion of the intervention, the researcher used the RTOP observation instrument (Sawada, Piburn, Judson, Turley, Falconer, Benford, & Bloom, 2002) to rate the treatment and control group participants
on their classroom implementation of instructional strategies that foster critical thinking development. Also, students in both the treatment and control group participants’ classes completed a critical thinking course evaluation form at pre- and post-intervention. The quantitative data collected from the classroom observations of the participants’ instruction and the student evaluations of the participants’ classes served to indicate the intervention’s effect on the participants’ instructional practice.

Additionally, at three time points during the intervention, student work samples were collected from both the treatment and control group participants’ classes. The student work samples were scored using the Critical Thinking Grid (Foundation for Critical Thinking, 2015) in order to evaluate the assignments’ effectiveness in cultivating the students’ critical thinking skills. Finally, following the intervention, semi-structured interviews with the treatment group participants provided the researcher with additional in-depth, qualitative data on the intervention’s effectiveness and the components to target for improvement.

**Intervention Findings**

Statistical analyses of the data revealed the intervention’s effect on the variables investigated in the study: knowledge of critical thinking instruction (mediating variable), pedagogical beliefs (moderating variable), and the adoption of critical thinking instructional practices (outcome variable). First, univariate analyses of the quantitative survey data revealed no significant effect of the intervention on the participants’ knowledge of critical thinking instruction. However, qualitative analyses of the open-ended survey responses revealed a positive change in the treatment group participants’ knowledge of the attributes of effective critical thinkers. Second, univariate analyses of
the quantitative survey data revealed no significant effect of the intervention on the participants’ overall pedagogical beliefs regarding critical thinking instruction. However, multivariate analyses revealed significant treatment effects on two specific indicators of pedagogical beliefs: the participants’ beliefs regarding the need to integrate critical thinking into the curriculum and their beliefs regarding the need for additional training in critical thinking instruction.

In addition, statistical analyses of the data revealed mixed findings regarding the intervention’s effect on the participants’ critical thinking instructional practice. According to univariate analyses of the course evaluation data, while students tended to provide their teachers with relatively high evaluation scores, no significant change in the participants’ practice occurred following the intervention. However, according to the RTOP observation data, the treatment group participants experienced significant, positive change in their instructional practice while the control group participants experienced no significant change in their practice following the intervention. Importantly, whereas the control group participants’ mean RTOP scores remained in the Level II (teacher-centered) range at pre- and post-intervention, the treatment group participants’ mean RTOP scores transitioned from a Level II (teacher-centered) rating to a Level III (student-centered) rating. In addition, the magnitude of the effect size produced in the treatment group ($\eta^2 = .626$) exceeded the effect size needed to demonstrate the intervention’s practical significance ($\eta^2 = .42$). Therefore, according to analyses of the RTOP data, the intervention produced a positive, significant effect on the treatment group participants’ critical thinking instructional practice and produced no observable effect on the control group’s practice.
In addition to the course evaluation and RTOP data, the critical thinking assignments implemented at three time-points in the participants’ classes provided additional evidence of the intervention’s effectiveness. Univariate analyses of the assignment scores, determined using the Critical Thinking Grid (Foundation for Critical Thinking, 2015), revealed a significant, positive change in the treatment group’s assignment scores relative to the control group’s assignment scores at the second time-point. In addition, linear regression analyses performed on the treatment and control groups’ assignment scores at the three time-points revealed a significant association between the treatment group’s mean assignment scores and time. However, linear regression analyses revealed no significant association between the control group’s mean assignment scores and time.

Finally, qualitative analyses of the semi-structured interview data, collected from the treatment group participants at post-intervention, revealed additional evidence of the intervention’s effectiveness in producing the desired outcomes. Primary and secondary coding cycles led to the emergence of three key themes that characterized the participants’ responses: time, support, and focused. Overall, the participants positively acknowledged the ongoing nature of the intervention and the ample time it allotted for practicing the learned critical thinking strategies and reflecting on their professional practice. In addition, in general, the participants expressed appreciation for the extensive amount of support they received from the researcher during the mentoring sessions, and from their peers by collaboratively reflecting on their practice and observation feedback. The participants also positively acknowledged the support they received in learning how to effectively apply the learned instructional strategies to their specific classroom context.
Qualitative analyses of the interview responses also revealed that the intervention had a positive influence on the participants’ knowledge of critical thinking instruction, pedagogical beliefs about student-centered learning, and adoption of critical thinking instructional practices. Finally, analyses of the participants’ interview responses revealed that the provision of additional time for training in the accurate and reliable use of the RTOP instrument and Critical Thinking Grid might enhance the intervention’s effectiveness in the future.

Overall, the professional development intervention findings suggest the treatment positively influenced the participants’ professional practice in the area of critical thinking instruction. The intervention’s minor to moderate effect on the treatment group’s knowledge and pedagogical beliefs suggests the intervention included an additional mediating variable that was essential for producing the observed outcome: increased adoption of critical thinking instructional practices. In particular, the support provided over time – by the researcher, the mentoring sessions, instructional resources, observation feedback, and peer collaborations – was a critical component that positively contributed to the participants’ adoption of critical thinking instruction. While the study design was limited by the small sample size and the researcher’s role as the Science Department Chair, the intervention provides a promising framework that may be adapted to similar settings in order to promote the adoption of critical thinking instructional practices.
Chapter 1

Introduction

In recent years, educational reform initiatives that place an increased emphasis on students’ development of 21st century skills challenge schools across the nation to improve student outcomes (Garet et al., 2001). Among the 21st century skills promoted by reform efforts include critical thinking, collaboration, problem-solving, creativity, and the innovative use of technology (Partnership for 21st Century Skills, 2008). In order to be successful in the 21st century, students must be able to collaborate with others and apply prior knowledge to solve complex, novel problems in real-world settings (Ertmer & Newby, 1993). The ability to effectively tackle these complex problems requires advanced critical thinking, a 21st century skill embraced by recent reform initiatives (Common Core, Undated; National Commission on Teaching and America’s Future, 1996; Partnership for 21st Century Skills, 2008) but underdeveloped among high school graduates (Pinkney & Shaughnessy, 2013).

School systems serve the vital role of responding to educational reform efforts and preparing students to be productive citizens in the 21st century. Public schools, under governmental control, are encouraged to adhere to policy decisions that dictate the implementation of reform initiatives. Conversely, private schools, subject to less bureaucratic control, experience greater flexibility in the adoption and implementation of policy decisions and curricular goals (Alt & Peter, 2002; Bidwell & Dreeben, 2003). This greater autonomy produces a private school culture in which the established practices and policies reflect the values of the school culture and the desires of parents. Although favored by most private school stakeholders, this level of autonomy creates a unique
dynamic in which the policies implemented may deviate from the reform initiatives encouraged by national experts in education (Lubienski et al., 2008a). Although many private schools value and promote critical thinking development, their discretionary adherence to policy may hinder the consistent implementation of evidence-based practices that enhance student outcomes.

**Overview of the Problem of Practice**

The lack of development of critical thinking skills continues to impede students’ preparedness for the rapidly evolving demands of the 21st century (Ertmer et al., 2012). Among the factors that contribute to the inadequate development of these skills are school structure and leadership, teacher collaboration and agency, professional development and evaluation systems, and teacher beliefs and practices (Bidwell & Yasumoto, 1999; Coburn, 2004; Desimone et al., 2002; Ertmer et al., 2012; Jacob & Walsh, 2011; Rafferty, 2003). Evidence suggests that innovative pedagogy that promotes complex problem-solving greatly enhances the development of critical thinking skills (Garet et al., 2001). However, within the independent, private school sector, traditional pedagogical beliefs often do not align with student-centered, critical thinking instructional practices (Dosen et al., 2004; Ertmer et al., 2012). Furthermore, professional development and teacher evaluation programs (i.e., programs that evaluate the teachers’ effectiveness in producing positive student outcomes) often inadequately foster teachers’ transition to 21st century educational approaches (Garet et al., 2001; Jacob & Walsh, 2011). To better understand the etiology of the problem in the secondary, private school setting, this chapter will examine the following underlying factors: teacher self-efficacy
beliefs, pedagogical beliefs, teacher collaboration, professional development, and teacher evaluation systems.

Figure 1

Factors Contributing to the Inadequate Adoption of Critical Thinking Instruction in Independent Schools

Literature Review: Theoretical Framework

In order to be successful in the 21\textsuperscript{st} century, students must develop critical thinking skills that enable them to solve complex problems in real-world settings (Garet et al., 2002; Pinkney & Shaughnessy, 2013). Critical thinking encompasses multiple higher-order cognitive abilities, including: analysis, inference, evaluation, inductive and deductive reasoning, explanation, and self-regulation (Yang, Gamble, Hung, & Lin,
In education, these skills are developed through the application of practices supported by cognitive and constructivist learning theories.

**Cognitive Learning Theory**

Critical thinking involves the application of higher-order cognitive abilities that the learner develops through educational experiences (Ennis, 1987; Pinkney & Shaughnessy, 2013). According to information processing theories, information is received by the learner through sensory input, processed and encoded within the learner’s memory stores, and later retrieved to enhance learning (Ertmer & Newby, 1993). The information encoded in long-term memory may be integrated with prior experiences to facilitate the transfer of knowledge to novel contexts (Ertmer & Newby, 1993). Critical thinking skills, such as analysis, inference, and evaluation, are required in order for learners to transfer their prior knowledge to novel situations requiring complex problem-solving and innovation (Ennis, 1987; Pinkney & Shaughnessy, 2013). According to Bloom’s Taxonomy (Bloom, 1956), these skills are located at the apex of a thinking hierarchy and must be acquired via the learner’s progression through the cognitive rungs of the ladder (Pinkney & Shaughnessy, 2013).

Similar to Bloom’s Taxonomy, Piaget’s theory of cognitive development establishes four stages (Sensorimotor, Preoperational, Concrete Operational, and Formal Operational) through which the learner naturally progresses with age (Piaget, 1970; Pinkney & Shaughnessy, 2013). In this cognitive development theory, children interact with their environment to develop schema that allow them to progress into the next stage of cognition (Commons & Richards, 2002). In order to think critically about abstract principles and apply higher-order thinking skills to solve complex problems, individuals
must reach the Formal Operational stage, or *stage 4*, of cognition (Piaget, 1970; Pinkney & Shaughnessy, 2013). The use of *stage 4* thinking enables learners to deeply analyze content and to solve complex problems through the application of critical thinking skills such as inductive and deductive reasoning (Ennis, 1987; Paul & Elder, 2001).

The learner’s progression through Bloom’s Taxonomy or Piaget’s stages of cognition requires the application of metacognition, or self-monitoring skills. Students with developed metacognitive abilities establish learning goals, develop strategies for achieving their goals, and monitor and evaluate their progress (Flavell, 1979). The learning process is centered within the learner and facilitated by external resources, including the teacher and educational materials. Students who employ metacognitive strategies, such as self-regulatory learning, promote the development of their cognitive skill-sets, including their critical thinking abilities (Sungur & Tekkaya, 2006).

**Constructivist Learning Theory**

According to constructivist learning theories, knowledge is actively constructed by the learner and is dependent upon the learner’s prior experiences and mental framework (Von Glasersfeld, 2005). In social constructivism, learners collaborate with peers to construct their understanding of concepts. Learners develop their critical thinking skills through in-depth collaboration and the application of their constructed knowledge to solve complex, novel problems (Ertmer & Newby, 1993). Sociocultural perspectives place great emphasis on the interaction of students with their environment and learning resources to enhance the development of their higher-order thinking skills (Gee, 2008). Through active collaboration with peers and more knowledgeable adults or mentors, the learner progresses through a zone of proximal development to develop higher-level
cognitive skills and a deeper understanding of concepts (Vygotsky, 1978). According to these learning theories, critical thinking skills are best developed when learning is situated within an authentic, real-world context and provides students with ample opportunities for collaboration with one another and experts in the field (Gee, 2008; Resnick, 1987).

**Application of Learning Theories**

Teachers play a crucial role in the development of students’ critical thinking skills. An educator who embraces cognitive and constructivist learning theories is more likely to integrate in the classroom innovative instructional strategies that cultivate the students’ critical thinking skills (Ertmer et al., 2012). These educators provide authentic, challenging, student-centered learning experiences that promote the progression to the Formal Operational stage of cognition (Pinkney & Shaughnessy, 2013). According to cognitive and constructivist theorists, knowledge acquisition requires the student to be actively engaged in the learning process. To ensure the student’s cognitive development, the teacher must provide opportunities for the integration of complex, critical thinking tasks, including reasoning, problem-solving, and information-processing (Ertmer & Newby, 1993). According to constructivist theorists, the student constructs knowledge through the interaction of internal cognitive processes and external environmental factors (Ertmer & Newby, 1993). Thus, the role of the teacher is to provide student-centered experiences in which the learners internalize concepts and apply their knowledge to authentic, real-world problems (Elder & Paul, 2008; Ertmer & Newby, 1993). Students, the primary cultivators of their knowledge in these learner-centered environments,
develop their critical thinking skills as they apply their knowledge in meaningful ways (Elder & Paul, 2008).

However, in spite of research supporting the use of cognitive and constructivist strategies and a general consensus among educators of the importance of critical thinking instruction, traditional, teacher-centered instructional practices persist in private, high school classrooms (Chandler, 1999; Elder & Paul, 2010; Lubienski et al., 2008a). For example, a traditional strategy commonly used in secondary classrooms is the lecture format, which aims to impart knowledge to learners rather than teach them to think critically and construct their own understanding of concepts (Tiwari, Lai, So, & Yuen, 2006). In addition, although current research emphasizes a greater focus on depth of content knowledge and development of critical thinking skills (Abrami et al., 2015), traditional practices often focus on breadth of content knowledge and the acquisition of facts (Tiwari et al., 2006). These rigid, teacher-centered practices often inadequately promote the deeper learning and critical thinking encouraged by student-centered, cognitive- and constructivist-based practices (Ertmer & Newby, 1993).

Education that embraces student-centered, evidence-based practices facilitates students’ progression through the cognitive stages and thus promotes their critical thinking development (Pinkney & Shaughnessy, 2013). However, in spite of Piaget’s assertion that all learners are capable of progressing through the stages of cognitive development, many adolescents do not reach the advanced Formal Operational stage of cognition (Pinkney & Shaughnessy, 2013). Consequently, these individuals are unable to achieve to their greatest potential in high school classes that require deeper thinking and complex problem-solving. The transition to student-centered, cognitive and constructivist
instructional practices is a key step in promoting students’ progression through the stages of cognitive development (Ertmer & Newby, 1993; Gee, 2008; Pinkney & Shaughnessy, 2013). This research thus aims to address the primary factors that constrain the shift to student-centered, critical thinking instructional practices in the secondary, private school context.

**Literature Review: Empirical Framework**

**Private School Context**

The particular problem of inadequate critical thinking development among students in the private, high school sector originates largely from the school choice movement and market theory. The school choice movement reflects the commonly-held belief that the “private school effect” produces more positive outcomes for students (Lubienski et al., 2008a). However, contrary to this popular belief, public schools often outperform private schools in student achievement (Lubienski et al., 2008a; Lubienski, Crane, & Lubienski, 2008b). The converse assumption, that private schools outperform demographically-similar public schools, is largely supported by market theory and the strategic placement of schools within a competitive school market (Lubienski et al., 2008a).

In spite of the school choice movement and the alleged “private school effect,” recent research confirms that many public schools, when demographics are held constant, outperform private schools regardless of school type (Braun, Jenkins, & Grigg, 2006; Lubienski et al., 2008a). Earlier studies, based on the 1980 High School and Beyond (HSB) data set, suggested private school students, when socioeconomic status was held constant, outperformed public school students on achievement tests (Coleman, James,
Hoffer, & Kilgore, 1982). Some of these studies identified specific characteristics of private schools, such as the school climate, that positively correlated with student achievement (Bryk, Lee, & Holland, 1993). However, more recent studies based on the National Assessment of Educational Progress (NAEP) data set reveal slightly higher mathematics achievement in public schools when compared to demographically-similar private schools (Braun et al., 2006; Lubienski et al., 2008a; Lubienski et al., 2008b). These studies raise doubts about the commonly-held assumption that the private school effect produces superior student outcomes when compared to the public school sector.

To further understand the effect of school type on student mathematics achievement, Lubienski et al. (2008a) examined school processes that received little attention in earlier studies based on mathematics data sets (HSB and NAEP). Specifically, using multilevel analyses of the 2003 NAEP mathematics data set, the researchers investigated the degree to which reform-oriented mathematics instructional practices, promoted by The National Council of Teachers of Mathematics (NCTM, 1989, 2000, 2014), account for differences in student achievement across the multiple school types. In this large-scale study, the researchers surveyed more than 270,000 students, in addition to their teachers and administrators, from more than 10,000 public, Catholic, Lutheran, conservative Christian, other independent private, and charter schools.

The National Council of Teachers of Mathematics (NCTM, 1989, 2000, 2014) encourages a shift to student-centered practices that rely more on the strategic use of tools and models and less on rote memorization to promote students’ improved number-sense and critical thinking. Among the instruction-related variables Lubienski et al. (2008a) observed in the participating private schools, the prevalence of NCTM-supported
instructional practices served as the most frequent predictor of high levels of student achievement. The results revealed a positive association between students’ mathematics achievement and teachers’ adoption of reform-oriented mathematics instructional practices, with a greater prevalence of reform-oriented practices in public schools than in private schools (Lubienski et al., 2008a). Therefore, the study not only confirmed that many public school students outperformed private school students on the 2003 NAEP mathematics test, but it also revealed a significant, positive association between the use of evidence-based instructional practices and enhanced student outcomes (Lubienski et al., 2008a).

In spite of recent findings that indicate higher standardized test performance among public school students, the assumption by the public remains that private schools are academically superior to public schools. This belief stems largely from market theory, an economics perspective characterized by increased competition between private schools as they strive to meet the demands of their stakeholders (Berends et al., 2010; Lubienski et al., 2008a). Those schools that successfully meet the demands of stakeholders are more likely to maintain their competitive edge in the private school market (Berends et al., 2010).

In order to attract prospective students in the competitive private school market, many private schools adopt and advertise innovative education initiatives (Berends et al., 2010). For example, many private schools adopt education technology initiatives in order to appear innovative and improve their market standing in the 21st century. However, these “external incentives” reported by private schools often inadequately take into account the internal, “black box” processes that occur within these institutions (Berends
et al., 2010; Lubienski et al., 2008a). For example, whereas technology is a highly
desirable and necessary component of any school program striving to prepare students for
the 21st century, it is the effective integration and use of technological resources in a
student-centered, cognitive or constructivist classroom environment that cultivates deeper
learning and critical thinking skills (Ertmer et al., 2012). Inadequate emphasis on the
efficient use of school resources to promote thinking and student achievement leads to
“black box” institutions that appear desirable externally but lack effective education
improvement plans internally (Berends et al., 2010; Lubienski et al., 2008a).

Berends et al. (2010) examined the processes that occur within the “black box” of
schools of choice to determine their effects on student achievement compared to
traditional public schools. Specifically, these researchers sought to determine the validity
of arguments that claim the school choice movement improves student outcomes.
Advocates of school choice assert that the inherent autonomy of private schools and their
location in a competitive market improve student achievement by encouraging innovation
in response to stakeholder preferences (Berends et al., 2010). In contrast, critics of the
school choice model often adhere to institutional theory which purports that schools,
public and private alike, subject to bureaucratization overlook important internal
processes, such as classroom instruction and professional learning, as they strive to
maintain compliance with established rules and mandates (Berends et al., 2010). Thus,
through a comparison between schools of choice and traditional public schools, Berends
et al. (2010) sought to unveil the internal school processes that promote student
achievement.
Berends et al. (2010) used propensity score analyses to compare test scores of students from charter schools to matched students from public schools and to determine the impact of various internal school processes on any observed achievement gains. The internal processes that served as indicators of the school’s focus on learning included: academic instructional innovation, instructional program coherence, time on task, focus on achievement, and school characteristics. The study utilized data from the Northwest Evaluation Association (NWEA), a partner with the National Center on School Choice (NCSC), and included student reading, language arts, and mathematics test scores from more than 4 million students from more than 2,000 districts across the nation. Statistical analyses were performed on the student test score data from 2002 through 2006. In addition, in 2006, the researchers administered surveys to teachers and principals in 62 charter schools and their matched NWEA-tested public schools.

The results of Berends et al.’s (2010) study indicated no significant differences in the gain in mathematics achievement between charter and public school students. Furthermore, among the internal processes measured, a teacher’s focus on achievement significantly increased student achievement, while a teacher’s focus on instructional innovation significantly decreased student achievement (Berends et al., 2010). These findings suggest that a heavy emphasis on innovation alone is an ineffective strategy for improving student outcomes. Instead, internal processes that focus on the strategic use of innovative resources to enhance learning may more effectively translate to positive student outcomes (Davies & Davies, 2014).

The variables investigated in these studies of private school effectiveness represent internal processes, namely instructional practices, that are positively associated
with student achievement. The internal processes specific to these investigations included reform-oriented, student-centered instructional practices that promote deeper learning and critical thinking. Furthermore, the research suggests that an emphasis on innovation without adequately addressing the internal processes that promote student achievement decreases a school’s effectiveness (Berends et al., 2010; Davies & Davies, 2014). Yet, in spite of research supporting the positive association between evidence-based, reform-oriented practices and student outcomes, these instructional practices are less prevalent in private schools than in demographically-similar public schools (Lubienski et al., 2008a). As a result, private school students are less likely to actively engage in cognitive and constructivist learning environments that support the development of their critical thinking skills.

The school choice research reveals a downside to the greater autonomy exhibited by educators in the private school sector. Although generally preferred by school stakeholders, this autonomy permits private school educators to implement initiatives that may insufficiently reflect current research supporting cognitive and constructivist learning approaches (Berends et al., 2010; Lubienski et al., 2008a; Spillane, 2000). This research analysis thus aims to examine the factors that hinder the adoption and effective implementation of reform-oriented, evidence-based critical thinking instructional practices in private schools.

**Instructional Practices in Private Schools**

The implementation of student-centered, reform-oriented instructional practices supported by cognitive and constructivist learning theories is essential to the development of students’ critical thinking skills (Pinkney & Shaughnessy, 2013). Among the school
factors that most directly contribute to the adoption of instructional practices include: teacher efficacy, pedagogical beliefs, teacher collaboration, professional development, and teacher evaluations. Teacher efficacy refers to a teacher’s level of confidence in implementing instructional strategies and enhancing student achievement (Yeh, 2006). Pedagogical beliefs refer to the learning theories embraced by a teacher and are generally reflected in the teacher’s practice (Ertmer et al., 2012). Furthermore, research consistently supports the positive association between teacher collaboration and the adoption of innovative instructional strategies (Chong & Kong, 2012). Finally, professional development and teacher evaluation systems influence pedagogy by providing support and feedback that foster change in a teacher’s practice. Private school factors that constrain teacher efficacy, collaboration, and professional growth in turn hinder the integration of innovative practices that promote students’ critical thinking development (Chong & Kong, 2012; Holzberger et al., 2013).

**Teacher efficacy.** A teacher’s self-efficacy strongly predicts his ability to effectively promote the development of students’ critical thinking skills (Holzberger et al., 2013). In his social cognitive theory, Bandura (1997) defines self-efficacy beliefs as the confidence in one’s ability to perform a particular task. In education, teacher self-efficacy beliefs significantly influence both teacher and student outcomes (Klassen, Tze, Betts, & Gordon, 2011). A teacher’s positive self-efficacy beliefs promote quality instruction which, in turn, further enhances self-efficacy beliefs (Holzberger et al., 2013). Holzberger et al. (2013) revealed this reciprocal interaction between self-efficacy beliefs and instructional quality through the examination of data collected from the Professional Competence of Teachers, Cognitively Activating Instruction, and the Development of
Students’ Mathematical Literacy (COACTIV) study, administered by the Organization for Economic Cooperation and Development (Holzberger et al., 2013). In this study, teacher participants (N=155 secondary mathematics teachers) completed a modified version of Schwarzer, Schmitz, and Daytner’s (1999) Teacher Self-Efficacy Scale. Statistical analyses examining longitudinal effects of teacher self-efficacy on instructional quality and vice versa confirmed the reciprocal relationship between these variables.

Holzberger et al. (2013) further measured the effects of teacher self-efficacy beliefs on instructional quality using cross-sectional analyses of both teacher (N=155) and student (N=3,483) ratings on three subscales developed for the COACTIV study. The measures of instructional quality assessed by the three subscales included: cognitive activation, classroom management, and individual learning support. The researchers define “cognitive activation” as the degree to which the adopted instructional practices challenge the students and activate their cognitive abilities. They define “classroom management” as the level to which the teachers provide a structured and orderly environment. They define “individual learning support” as the extent to which teachers monitor their students in the learning process. The results revealed a significant, positive association between teacher self-efficacy beliefs and both teacher and student ratings of all three of the instructional quality measures (cognitive activation, classroom management, and individual learning support). These findings confirm not only the significant, positive effect of teacher self-efficacy on instructional practices but also the positive, reciprocal effect of quality instruction on self-efficacy (Holzberger et al., 2013).
Therefore, this positive and reciprocal relationship between self-efficacy and instruction may either foster or hinder teacher efficacy in the area of critical thinking instruction.

In addition to its effects on pedagogy, teacher self-efficacy beliefs in the area of critical thinking instruction are greatly influenced by a teacher’s personal traits. Yeh (2006) demonstrated the relationship between personal traits, guided practice, and pre-service teachers’ level of efficacy in the area of critical thinking instruction. Pre-service teachers (N=178) enrolled in a teaching program in Taiwan performed two consecutive interactive teaching simulations using the Computer Simulation for Teaching General Critical Thinking Skills (CS-TGCTS) program developed by Yeh (1997). The CS-TGCTS interactive interface provided the participants with integrated guided practice within a simulated classroom environment. The first simulation included inventories of teaching efficacy and personal traits, a training session on classroom teaching, and a framework to improve self-awareness and reflective teaching. The simulation also included measures of effective teacher behaviors and research-based literature in the area of critical thinking instruction. The second simulation included guided practice in a classroom teaching session and provided training intended to improve participants’ teaching skills and personal efficacy in the area of critical thinking instruction.

The CS-TGCTS guided simulations administered in Yeh’s (2006) study also included instruments to measure the participants’ personal traits, including their intrapersonal intelligence, their critical thinking (CT) dispositions, and their thinking styles. The instruments used to measure these personal traits included: The Inventory of Personal Teaching Efficacy in Critical Thinking (IPTE-CT), the Questionnaire of Intrapersonal Intelligence (QII), the Inventory of Critical Thinking Dispositions (ICTD),
and the Inventory of Thinking Styles (ITS). Upon completion of the guided simulations, participants with a high level of intrapersonal intelligence, strong CT-disposition, and preference for judicial or legislative thinking experienced significant improvements in teacher efficacy when compared to participants with low intrapersonal intelligence, weak CT-dispositions, and a preference for executive thinking styles (Yeh, 2006). According to Yeh (2006), individuals with judicial and legislative thinking styles tend to evaluate and analyze situations and to apply their own rules and creativity when solving problems. Conversely, individuals with executive thinking styles prefer to perform well-defined and structured tasks (Yeh, 2006). Therefore, a teacher’s critical thinking disposition and preferred thinking style are strong predictors of teacher self-efficacy beliefs in the area of critical thinking instruction and a teacher’s likelihood for growth following a guided learning experience. In turn, a teacher with enhanced critical thinking self-efficacy beliefs is more confident to implement novel, research-based practices that foster students’ critical thinking development (Yeh, 2006).

In addition to self-efficacy, teachers’ collective efficacy greatly influences their implementation of instructional practices. Bandura (1997) defined collective efficacy as “a group’s shared belief in its conjoint capabilities to organize and execute the courses of action required to produce given levels of attainments” (p. 477). Bandura (1997) recognized that teachers do not work in isolation and that their productivity is closely associated with their beliefs about the capabilities of the group as a whole. Similar to the concept of teacher self-efficacy beliefs, collective efficacy beliefs are positively associated with the group members’ motivation to implement instructional strategies that enhance student outcomes. When private school teachers accustomed to high levels of
autonomy are pressured to change their practice in response to reform initiatives, their successful adoption of the promoted strategies is greatly influenced by both their self- and collective efficacy beliefs (Klassen et al., 2011). Teachers with positive self- and collective efficacy beliefs are more likely to adopt and implement evidence-based practices that cultivate students’ critical thinking skills.

**Teacher collaboration.** The collective efficacy construct assumes that teachers typically perform tasks as a collective, or collaborative, unit (Bandura, 1997). Extensive research supports the positive association between teacher collaboration and adoption of quality instructional practices (Bidwell & Yasumoto, 1999; Chong & Kong, 2012; Robinson, 2012; Yasumoto, Uekawa, & Bidwell, 2001). The degree to which teachers collaborate in their practice is thus a powerful indicator of the likelihood that they will adopt strategies that foster students’ critical thinking development. Bidwell and Yasumoto (1999) investigated this phenomenon by examining the extent to which high school academic departments serve as collegial networks that promote improvement in teacher practice. To measure the degree to which participation in collegial networks influences the adoption of progressive pedagogical practices, Bidwell and Yasumoto (1999) analyzed survey data collected from faculty (N = 338) from 13 diverse public and private schools, with 30 to 300 faculty members per school. Survey data analyses indicated that the cohesion of a collegial network was positively associated with the prevalence of progressive pedagogical beliefs among its members (Bidwell & Yasumoto, 1999). Furthermore, Chong and Kong’s (2012) analyses of qualitative data collected from a private high school revealed that faculty members (N = 10) who engaged in ongoing collaboration were more motivated to adopt innovative instructional practices.
Conversely, the lack of teacher collaboration decreased both teacher efficacy and motivation to improve instruction (Chong & Kong, 2012).

In public and private schools faced with increasing bureaucratization and pressure for reform, the strength of faculty collegial networks decreases due to the teachers’ lack of control over workplace decisions (Bidwell & Dreeben, 2003; Bidwell & Yasumoto, 1999). At a time when most schools are experiencing increased pressure to improve student preparedness for the 21st century, private schools are especially susceptible to the demands of stakeholders desiring improved school outcomes (Bidwell & Dreeben, 2003). In private schools where teachers are accustomed to greater autonomy, this increased pressure for change hinders the teachers’ collegial social control (Bidwell & Yasumoto, 1999). In turn, as the teachers perceive growing constraints to their instructional autonomy, both their ability to solve instructional problems and their motivation to adopt reform-oriented practices decrease (Bidwell & Dreeben, 2003; Bidwell & Yasumoto, 1999; Chong & Kong, 2012; Coburn, 2004).

Coburn (2004) investigated the impact of change initiatives on teacher practice through a qualitative, cross-case study of three teachers’ pedagogical responses to a school’s on-going reform initiative. Although the results are limited by the small sample size, the research design allowed for an in-depth examination of the effects of institutional pressure for reform on teachers’ instructional practice. The findings, that the institutional environment strongly influences pedagogy, confirmed that increased pressure for reform in autonomous private schools decreases teacher motivation and agency to implement innovative instructional practices (Coburn, 2004). In addition, private school teachers frequently work in isolation within their academic departments, a
phenomenon that limits the transfer of knowledge across disciplinary boundaries (Krishnan, 2009). Therefore, the high level of autonomy in private schools hinders teachers’ cross-collaboration and thus adoption of innovative pedagogy that cultivates students’ critical thinking skills.

**Pedagogical beliefs.** In addition to teacher efficacy and collaboration, teachers’ established beliefs about student learning greatly influence their adoption of critical thinking instructional practices (Smith, 2000). Factors that influence a teacher’s pedagogical beliefs include teaching experience, the teacher’s prior knowledge about learning, and philosophies promoted through teacher preparation and professional development programs (Bai & Ertmer, 2008; Smith, 2000). Recent educational reform initiatives emphasize the transition from teacher- to student-centered pedagogical practices (Coburn, 2004; Partnership for 21st Century Skills, 2008). In private schools, where teacher-centered instructional practices persist, this transition may be especially challenging among veteran teachers with firmly-established pedagogical beliefs (Smith, 2000).

To investigate the effect of teachers’ pedagogical beliefs on their practice, Smith (2000) followed throughout the course of a year a veteran mathematics teacher as she struggled to align her traditional instructional practices with the more student-centered and problem-solving approaches central to the school’s newly-adopted Visual Mathematics (Bennett & Foreman, 1991) reform program. The Visual Mathematics program emphasizes the role of the teacher as a facilitator and the students as the constructors of their mathematics’ knowledge (Bennett & Foreman, 1991). Analyses of the in-depth, qualitative data, which included the teacher’s journal entries, interview
responses, and artifacts from professional development sessions, provided evidence that the teacher’s established, teacher-centered beliefs about student learning served as a primary obstacle to the effective adoption of the promoted student-centered, reform-oriented practices. The results from Smith’s (2000) small-scale study support findings from similar, larger-scale studies (Ertmer et al., 2012; Lubienski et al., 2008) that suggest traditional pedagogical beliefs serve as a barrier to the effective adoption of 21st century reform initiatives, to include those that promote critical thinking instruction.

**Technology use.** With the current push to promote digital literacy in schools across the nation (Partnership for 21st Century Skills, 2008), a teacher’s use of technology for instructional purposes provides powerful evidence of the alignment between pedagogical beliefs and practice. Teachers with student-centered, reform-oriented beliefs tend to integrate technology in a manner that fosters students’ critical thinking development (Ertmer et al., 2012). To investigate the connection between teacher beliefs and practice, Ertmer et al. (2012) examined the extent to which traditional beliefs serve as a barrier to the integration of student-centered technology practices in the classroom. The researchers utilized a multiple case-study design in which they analyzed the beliefs and practices of 12 K-12 teachers. The findings indicated that technology integration practices reflect the teacher’s espoused beliefs. That is, educators with traditional, teacher-centered beliefs were less likely to integrate technology in a student-centered environment that promotes the development of critical thinking skills (Ertmer et al., 2012). Therefore, in schools where teacher-centered pedagogical beliefs persist, technology is often inadequately utilized to support students’ critical thinking development.
In spite of many teachers’ adherence to traditional pedagogical beliefs, private schools invest in extensive technological resources to improve educational outcomes (Dosen, Gibbs, Guerrero, and McDevitt, 2004). In the private sector, schools are especially susceptible to the demands of external stakeholders who guide reform efforts and the allocation of resources (Bidwell & Dreeben, 2003). Whereas entrepreneurship fostered by technological innovation is a key ingredient for success in the 21st century (Partnership for 21st Century Skills, 2008), a school’s procurement of technology resources by itself does not promote critical thinking development (Gamoran & Long, 2006). Instead, when technological innovation is the primary focus of private institutions seeking a competitive edge in the market niche, this strategy produces a significant negative impact on student achievement (Berends et al., 2010). In the absence of strategies to effectively integrate and use the technology in a manner that improves student learning and skill development, these “Christmas tree schools” (p. 76) appear innovative without producing enhanced learning outcomes (Bryk, Easton, Kerbow, Rollow, & Sebring, 1994). If the procured technology resources are to effectively foster critical thinking development, they must be strategically integrated into instruction in a manner that actively engages students and improves their learning outcomes (Ertmer et al., 2012).

To investigate the effects of resource use on student learning outcomes, Davies and Davies (2014) examined the impact of resource allocation on student achievement. The participating English state schools sought to improve student achievement by emulating the autonomy and competition that characterized the more effective and affluent private schools in England. The researchers collected data from a cross-sectional
sample of 348 English private high schools and analyzed the effect on student achievement of the schools’ allocation of resources. The results revealed that private schools characterized by greater levels of autonomy, affluence, and competition in many cases did not allocate their resources to inputs, such as curriculum and instructional initiatives, which directly promote student achievement (Davies & Davies, 2014). Instead, these schools allocated most of their resources to staffing costs, including teacher and non-teaching staff wages. In addition, schools with a higher average income per student hired proportionally more teachers and non-teaching staff per student. Yet, the study results revealed no association between the number of teachers and non-teaching staff members employed by the school and the school’s value added as measured by student achievement (Davies & Davies, 2014). These findings suggest that many private institutions that have ample resources within their endowments still neglect to allocate adequate funds to educational initiatives that enhance student outcomes.

In order to enhance students’ critical thinking outcomes, technology resources must be allocated and utilized within the context of a student-centered learning environment. The student-centered environment that supports cognitive development is characterized by activities in which students apply prior knowledge to solve complex problems in novel contexts (Lei & Zhao, 2007). Furthermore, students who integrate higher-order computer skills within a social-constructivist learning environment experience significant gains in critical thinking development (McMahon, 2009). However, technology-supported constructivist practices are among the least frequently integrated in secondary school classrooms (Lei & Zhao, 2007).
To determine the extent to which secondary schools integrate technology in a constructivist, student-centered manner, Lei and Zhao (2007) investigated the effects of quantity and quality of technology use on student learning outcomes. The researchers differentiated technology use into four categories based on Bruce and Levin’s (1997) taxonomy of educational technology: “technology as media for inquiry, technology as media for communication, technology as media for construction, technology as media for expression” (Lei & Zhao, 2007, p. 286). Study participants included both students (N = 130) and teachers (N = 10) at an Ohio middle school equipped with ample technology resources (TV, computer projector, VCR, wireless Internet) in every classroom. Also, the school’s laptop program provided a laptop computer to every student. The researchers administered pretest (at the beginning of the school year) and posttest (at the end of the school year) Likert-scale surveys to determine the frequency with which the student participants engaged in high-quality educational technology uses. Semi-structured interviews conducted with the teacher (N = 10) and student (N = 9) participants at two time points during the school year further elucidated the types of technology used most frequently by students and the extent to which students engaged in high-quality, technology-supported learning tasks.

After collecting the survey and interview data, descriptive statistics provided the frequency with which students used different types of technology, and T tests and ANOVA analyses revealed the relationships between technology uses and changes in students’ GPA over time. The quality of a particular technology use was indicated by its effect on the students’ GPA over the course of the year. The technology uses that positively contributed (p < .05) to changes in students’ GPA included those that were
subject-specific (e.g., lab probes in science classes) and those that required students to construct knowledge of concepts (e.g., the creation of websites). However, the technology uses that positively contributed to changes in students’ GPA were among the least frequently used by the student participants. Instead, the students’ most frequent technology uses, such as emailing friends and using Microsoft Word for taking notes, produced no observable effect on GPA and, in some cases, negatively impacted the students’ GPA over time. Therefore, although the tested school was equipped with ample technology tools, the manner and frequency with which teachers generally integrated these tools into instruction was of inadequate quality to produce significant gains in students’ GPA over time (Lei & Zhao, 2007).

Dosen et al. (2004) further contributed to the research on educational technology use by investigating technology practices in nonsectarian and religious private schools. The researchers identified a primary obstacle to 21st century skill development as being the existence of a digital divide between simply having access to technological tools and teachers being capable of making effective use of these resources to enhance learning. The authors investigated this divide by surveying a sample of 412 principals in K-12 private schools to analyze the teachers’ level of access to and use of technology. Similar to the findings from Lei and Zhao’s (2007) study, the findings from Dosen et al.’s (2004) large-scale study indicated that, although the participating private schools had equal access to technology, the degree to which the teachers effectively utilized technology varied greatly across the schools. Whereas some schools implemented technology in a student-centered manner that promoted critical thinking development, many schools did not. Therefore, a primary barrier to the development of critical thinking skills is the lack
of consistency among private schools in their ability to integrate technology in a high-quality manner that enhances student learning outcomes (Dosen et al., 2004).

**Professional Development.** Effective professional development (PD) programs provide teachers with the education, guidance, and support needed to foster their adoption of innovative instructional practices that cultivate students’ critical thinking skills. However, the current research is limited in its ability to identify PD frameworks and practices that enhance teacher and student outcomes (Harris & Sass, 2011). Furthermore, the private school context poses unique challenges to the implementation of effective PD programs.

The inherent autonomy of private schools provides the flexibility to implement PD programs that align with the school-specific goals established and outcomes desired by the stakeholders (Lubienski et al., 2008a). Whereas some private schools emphasize reform-oriented instruction, others implement initiatives that emphasize more traditional practices that inadequately target critical thinking development (Desimone et al., 2002; Dosen et al., 2004). In addition, private school teachers report participating in fewer PD opportunities than do public school teachers (Lubienski et al., 2008a). Although the frequency with which teachers participate in PD activities is positively associated with student learning outcomes, the research is inconsistent in its ability to determine the extent and type of PD activities that positively influence student outcomes (Desimone et al., 2002). Whereas some research suggests that frequent exposure to a variety of PD activities improves student outcomes (Lubienski et al, 2008a), other research indicates that some forms of training negatively impact student achievement (Harris & Sass, 2011). For instance, in some cases, contemporaneous PD (i.e., PD which takes place during the
school day) negatively impacts student achievement when it takes place during the teacher’s normal class or planning time (Harris & Sass, 2011). In other cases, only delayed effects are observed, with negative student achievement effects observed during the PD acquisition year and positive student achievement effects observed in subsequent years (Harris & Sass, 2011).

Contributing to the challenge of improving teachers’ critical thinking instruction is the lack of available research and consistent findings in effective PD frameworks (Desimone et al., 2002; Garet et al., 2001; Harris & Sass, 2011). One indicator of PD effectiveness is the degree to which participation in PD programs enhances teacher productivity (Harris & Sass, 2011). However, research in this area is limited by the lack of accurate measures of teacher productivity following participation in PD activities (Harris & Sass, 2011).

Harris and Sass (2011) sought to overcome the shortcomings of previous studies (Clotfelter, Ladd, Vigdor, 2006; Feng, 2009) that ineffectively measured teacher productivity as an outcome of PD initiatives. The researchers examined the effects of pre-service, in-service, and informal on-the-job training on teacher productivity, as measured by student scores on mathematics and science standardized tests in elementary, middle, and high school grades. Using standardized test score data from all public school students, grades 3 to 10, who resided in Florida between the years 1999 and 2005, the researchers implemented an econometric model and estimation strategies to isolate the effects of teacher productivity on student achievement. The results revealed that, with the exception of middle school mathematics teachers, participation in in-service PD programs did not produce student achievement gains on standardized tests (Harris &
Sass, 2011). The failure of the in-service PD programs to positively influence student outcomes suggests that these programs may inadequately support teachers in their professional growth.

In order to ensure that PD programs improve teacher practice in the area of critical thinking instruction, they must be continually evaluated for their overall effectiveness in producing the desired goals. To do so, researchers must implement evaluation models that analyze school- and classroom-level data to determine the effects of PD on teacher learning outcomes. However, few studies provide frameworks for effectively evaluating PD programs on their ability to generate change in teacher practice (Belvis et al., 2013).

Belvis et al. (2013) sought to ameliorate this gap in the literature by applying existing evaluation models to assess the effectiveness of a mathematics PD program. The Teacher Education Program for Teaching Mathematics adopted by the participating schools relied heavily on reflective teacher practice to improve mathematics teaching and learning outcomes. That is, during the program, teachers collaboratively reflected on their practice to contemplate their own pedagogical skill-sets and to develop strategies, such as integrating technological tools in mathematics lessons, for improving learning outcomes. The researchers applied two existing evaluation frameworks, Pineda’s (2002) holistic evaluation model and Kirkpatrick’s (2005) four-level model, to assess teacher learning outcomes following their participation in the PD program. Both frameworks rely upon transfer, or the teacher’ ability to effectively apply the learned practices to the classroom context, as the primary indicator of the program’s effectiveness.
The study performed by Belvis et al. (2013) included 284 primary and secondary education teacher participants from 16 schools and utilized a mixed-methodology approach to thoroughly assess the mathematics program’s ability to produce change in the teachers’ practice. Qualitative data collected from questionnaires and interviews provided in-depth feedback regarding the extent to which participants were satisfied with the program, learned innovative practices, and transferred the learned skills to the classroom. Quantitative data included student performance on mathematics classroom assessments following the teacher’s implementation of the learned strategies. While the results revealed significant improvements in the participants’ learning of novel skills and teaching strategies, they also indicated tremendous variation in the degree to which teachers transferred different skill-sets to the classroom. For example, whereas 62.3% of participants reported improvements in their ability to guide students’ learning, only 25% reported improved abilities to promote the students’ co-construction of knowledge. Therefore, although the professional development program produced many positive learning outcomes for mathematics teachers, its effectiveness would be improved by targeted efforts to enhance the transfer of learned skills to the classroom setting.

Belvis et al.’s (2013) findings regarding the challenge of transfer are not surprising; extensive research suggests that knowledge acquired in professional development settings is rarely transferred to the classroom setting (Kelly, 2006; Resnick, 1989). In their study, Belvis et al. (2013) uncovered several obstacles to the effective transfer of learned practices to the mathematics classroom. First, teachers reported insufficient time in their schedules, due to their work responsibilities, to integrate new, innovative strategies into their lessons. Second, the complex nature of transferring novel
learning strategies to the classroom context poses challenges for teachers unaccustomed to introducing significant change to their traditional methods of instruction. And, third, the existence of different teacher teams for each course weakens the cohesiveness of the collective faculty unit, thus hindering the teachers’ ability to collaborate within professional learning communities. As previously discussed, teacher collaboration significantly and positively contributes to teachers’ adoption of innovative pedagogy (Bidwell & Yasumoto, 1999; Chong & Kong, 2012). Thus, multiple constraining factors, including inefficient collaboration with colleagues, hinder teachers’ ability to transfer the learned pedagogical practices to the classroom setting (Belvis et al., 2013). In order to improve students’ critical thinking development, these obstacles must be addressed and overcome so that teachers can successfully transfer evidence-based strategies to the classroom context.

**Teacher evaluations.** The implementation of research-based teacher evaluation systems enhances professional development outcomes and promotes the transfer of learned skills to the classroom context (Donaldson, 2013). Effective evaluation systems provide ongoing support and feedback to teachers as they work to improve their practice (Donaldson, 2013). They also facilitate the successful transfer of learned practices over time by assessing the teacher’s level of success with and adherence to the recommended pedagogical changes, and providing recommendations for improvement. However, many traditional evaluation systems fail to incorporate reliable and evidence-based measures that promote teachers’ professional growth. These systems rely upon infrequent observations performed by administrators and feedback measures that ineffectively
support ongoing growth in the teacher’s practice (Donaldson, 2013; Kimball, White, Milanowski, & Borman, 2004; Sharkey & Goldhaber, 2008).

Master (2014) investigated the ability of midyear formative evaluations, performed by school administrators, to accurately measure the effectiveness of teachers in an independently-managed public charter school district. The study included an analysis of 747 teacher evaluations performed by principals or assistant principals over a three-year period. The context provides a useful comparison to the independent, private school setting because, like many private school leaders, the participating administrators had unrestricted autonomy over the school’s personnel decisions. In contrast to most value-added measures of teacher effectiveness based predominantly on student achievement (Chetty, Friedman, & Rockoff, 2012; Goldhaber, 2002), the evaluative protocol utilized by the charter school administrators provided teachers with subjective feedback based on 47 different performance indicators. Master (2014) applied an exploratory factor analysis to the collected evaluation data to identify the teacher characteristics that best predict teacher effectiveness ratings.

Although the results of Master’s (2014) analyses indicated that the evaluation ratings successfully differentiated between teachers of varying effectiveness, the ability of the given evaluation protocol to effectively rate teacher practice is limited. Subjective evaluations, such as those implemented within the independent charter school district, provide insufficient critical feedback to promote improvement in teacher practice (Donaldson, 2013). Furthermore, the teacher effectiveness ratings are based on a single midyear assessment; yet, an accurate assessment of a teacher’s growth over time requires frequent observations conducted by multiple trained evaluators (Goe, Bell, & Little, 2013).
Finally, formative evaluative protocols that fail to stipulate ongoing teacher support and targeted professional development inadequately promote improvement in teacher practice (Belvis et al., 2013; Goe et al., 2008). Therefore, evaluation protocol implemented by autonomous school administrators may ineffectively improve teacher practice in the area of critical thinking instruction.

Statement of the Problem

Success in the 21st century requires advanced critical thinking abilities (Abrami et al., 2015; Partnership for 21st Century Skills, 2008). However, the autonomous nature of private, independent schools may hamper efforts to develop students’ critical thinking skills (Berends et al., 2010). Among the factors that most significantly contribute to the inadequate development of critical thinking skills is the teachers’ adherence to traditional, teacher-centered practices (Lubienski et al., 2008a). The school factors that constrain a teacher’s transition from traditional, teacher-centered practices to evidence-based, student-centered practices include: decreased teacher self-efficacy (Holzberger et al., 2013), traditional pedagogical beliefs (Ertmer et al., 2012), inadequate teacher collaboration (Bidwell & Yasumoto, 1999; Robinson, 2012), ineffective professional development programs (Desimone et al., 2002), and unreliable evaluation criteria (Donaldson, 2013).
**Project Objectives**

In order to better understand and effectively address the problem of teachers’ adherence to traditional instructional practices that hinder students’ critical thinking development, this project aims to achieve the following objectives:

1. To determine the extent to which current instructional practices in an independent, private school setting support the development of students’ critical thinking skills.
2. To identify the underlying factor(s) that most significantly hinder teachers’ adoption of critical thinking instructional practices in an independent, private school setting.
3. To develop and implement an intervention that targets the identified constraining factor(s) in an effort to improve teachers’ adoption of evidence-based, student-centered practices and ultimately enhance students’ development of critical thinking skills.
Chapter 2

Needs Assessment Study

A needs assessment study was designed to understand the extent to which critical thinking instruction occurs at a secondary, independent, private school. In addition, the study assessed the degree to which factors associated with critical thinking pedagogy exist at the school. For the purpose of this needs assessment study, the scope of the problem focused on an examination of the following factors: teacher self- and collective efficacy beliefs, pedagogical beliefs, teacher collaboration, professional development, and teacher evaluation systems within the independent school setting. The ultimate goal of the study was to inform the development of an intervention that would most efficiently and effectively promote the adoption of critical thinking instructional practices among the teachers of the core subject areas of science, mathematics, social studies, and English.

Contextual Background

The school examined in this study is a member of a large consortium consisting of 120 independent schools serving more than 45,000 students. The consortium supports its member schools by providing regular professional development opportunities, monitoring the schools’ progress and curricula, protecting the schools from governmental control, and providing accreditation services to ensure alignment with the consortium’s established mission. The consortium provides member schools with ongoing learning and accreditation opportunities to promote continued progress towards 21st century educational standards.¹

While all member schools within the consortium are governed by a board of trustees and share the common mission to promote academic excellence, there are
numerous differences between them. In contrast to the public sector, the independent sector is unique as it provides parents with the opportunity to choose a school that best meets the needs of their child and family. From among the independent schools, parents may select religious or nonsectarian, coeducational or single-sex, day or boarding, and pre-K through secondary educational institutions. Furthermore, each independent school adheres to a unique philosophy and mission determined by its board of trustees in conjunction with the internal and external stakeholders that govern the school.

Due to their inherent autonomy, independent schools vary greatly in numerous factors that ultimately influence teacher practice and student achievement. These factors include but are not limited to: student composition (gender, socioeconomic status, race, and ethnicity), tuition, financial assistance, location (rural vs. urban), resources, teacher credentials, religious affiliation, curriculum, and the philosophies and learning outcomes valued by the school. In addition, students matriculate from a variety of schools and school districts, including public, private, or other independent schools. Each of the schools from which the students matriculate provides distinct educational experiences and values unique philosophies, as well. The extent to which a particular school, its board of trustees, and its stakeholders value critical thinking dictates the implementation of reform initiatives that support the development of this skill. However, due to the lack of standardization among the independent schools, there is much variability in the skills that are valued and promoted in the adopted reform initiatives. As a result, critical thinking instruction may be lacking in schools that place greater value on other initiatives or inadequately implement programs that target instruction.
The setting selected for this needs assessment study is a Catholic, independent school serving females in grades six through twelve. For the purpose of this study, the school will be referred to as “ICS” to represent an “Independent Catholic School”. The vast majority of students at ICS are Caucasian and from middle- to upper-middle class families. The prestigious school proudly reports an annual 100% college matriculation rate in addition to a high teacher retention rate. Furthermore, ICS requires teachers to be certified or in the process of earning certification in their content area. Most ICS teachers also hold graduate degrees in education or a field related to their content area.

ICS provided an ideal setting for the study as it is an independent school in the early stages of a 21st century reform initiative. The reform initiative encourages all teachers to more closely align their practice with 21st century educational standards. The 21st century skills most valued by the ICS community include collaboration, communication, creativity, critical thinking, and global citizenship. To support teachers in the reform process, the ICS administration initiated a pilot professional development program during the 2013-2014 school year. In spite of impressive teacher credentials and student graduation rates, after two years of implementation the program’s goals remained unachieved due to factors inherent to an autonomous, independent school culture. Among other challenges posed by the independent school culture, the reform program requires teachers to re-think and replace their traditional pedagogy with student-centered strategies more conducive to 21st century skill development. However, in spite of this primary objective of the reform program, traditional, teacher-centered practices persist across the curriculum at ICS.
Operationalization of the Variables

At ICS, a number of cultural and social constraints hindered the school’s efforts to promote 21st century instructional practices. First, numerous teachers exhibited resistance to the promoted change. In an effort to understand the origin of this resistance, the needs assessment study operationalized the variables identified as primary barriers to a teacher’s adoption of innovative practices. The independent variables investigated in this study include: teacher self- and collective efficacy beliefs, pedagogical beliefs, professional development, teacher evaluations, and teacher collaboration. The study operationalized these variables to determine the extent to which each of them supports the implementation of critical thinking instruction. In addition, the study investigated the extent to which teachers implement student-centered, critical thinking instructional practices in the core, high school subject areas of science, mathematics, social studies, and English. By doing so, relationships between the independent variables and the classroom instructional practices in each of the core subject areas could be determined. The core subject areas served as the focus for the investigation because most students are enrolled in these subjects and they provide the ideal setting for the development of critical thinking skills. In addition, a comparison of the teacher responses would reveal the extent to which differences exist within and between each subject area group, providing greater insight into the effectiveness of the current reform initiative at ICS.
Research Questions

The following research questions, which refer to teachers of the secondary, core subject areas of science, mathematics, English, and social studies, served to guide the needs assessment study:

RQ1: How do teachers perceive their ability, individually and collectively, to implement innovative instructional practices?

RQ2: To what extent do teachers’ pedagogical beliefs align with evidence-based practices that cultivate students’ critical thinking skills?

RQ3: How are teachers supported in the development of their professional practice in the area of critical thinking instruction?

RQ4: How are teachers evaluated and supported in their ongoing growth and effectiveness in the implementation of critical thinking instructional practices?

RQ5: To what extent does faculty collaboration foster the adoption of critical thinking instructional practices?

RQ6: To what extent do teachers implement practices that support the development of students’ critical thinking skills?

Methodology

Study Setting and Participants

ICS, an independent, Catholic, all-female school and member of a large, independent school consortium, provided the setting for the needs assessment study. The school serves female students in grades 6 through 12 and, at the time of the study, reported a total enrollment of 780, with approximately 600 in the high school. The study respondents included 220 high school students (grades 9 through 12) and 26 high school
teachers in the core subject areas of science, mathematics, social studies, and English. The student respondents (n = 220) provided a 30% response rate and included: 37 freshmen (17.7% of total respondents), 73 sophomores (34.9% of total respondents), 52 juniors (24.9% of total respondents), and 47 seniors (22.5% of total respondents). The teacher respondents (n = 26), from a population of 38 high school, core subject area teachers, provided a 68% response rate and included: 6 social studies, 8 science, 5 English, and 7 mathematics teachers.

Variables

**Dependent variable.** The teachers’ adoption of critical thinking instructional practices served as the dependent variable in the needs assessment study. The study provided evidence of the practices implemented specifically in the high school core subject areas of science, mathematics, social studies, and English.

**Independent variables.** Multiple school and teacher factors influence teachers’ adoption of critical thinking instructional practices. The purpose of the needs assessment study was to inform the development of an intervention that would effectively enhance the teachers’ adoption of critical thinking instructional practices at ICS. The following factors served as independent variables known to influence the adoption of critical thinking instructional practices (dependent variable): teacher self- and collective efficacy beliefs, pedagogical beliefs, professional development, teacher evaluations, and teacher collaboration. Therefore, the study sought to assess the extent to which each of the independent variables influences teachers’ critical thinking instructional practice at ICS. By doing so, a variable(s) could be identified to serve as a potential target of an intervention to improve the teachers’ adoption of critical thinking instructional practices.
**Teacher efficacy beliefs.** In education, self-efficacy generally refers to the degree to which a teacher believes he has the skills and competence to bring about learning among his students (Yeh, 2006). A positive relationship exists between teacher self-efficacy beliefs and instructional quality (Holzberger et al., 2013). Similarly, a teacher’s collective efficacy beliefs are positively associated with the group’s motivation to implement instructional strategies that enhance student outcomes (Bandura, 1997). Therefore, the study assessed the level of the teachers’ self- and collective efficacy beliefs in regards to critical thinking instruction.

**Pedagogical beliefs.** Pedagogical beliefs refer to the learning theories with which the teacher aligns himself and the instructional strategies he believes best promote student achievement (Ertmer et al., 2012). When compared to teachers with traditional, teacher-centered beliefs, teachers with student-centered beliefs are more likely to implement innovative instructional practices that promote the development of critical thinking skills (Ertmer et al., 2012). Therefore, the study assessed the degree to which teachers at ICS align themselves with student-centered versus teacher-centered beliefs.

**Professional development.** Professional development programs contribute significantly to an educator’s preparedness to provide critical thinking instruction (Duzor, 2011; Yeh, 2006). Quality professional development programs provide training in innovative practices that promote critical thinking skills and strategies for effectively transferring these practices to the classroom setting (Desimone et al., 2002; Duzor, 2011; Kelly, 2006). Therefore, the study assessed the extent to which current professional development initiatives at ICS provide training in critical thinking instruction.
Teacher evaluations. Teacher effectiveness is commonly measured by evaluating various aspects of a teacher’s practice. The adoption or development of an effective teacher evaluation system is critical to ensuring the ongoing professional growth of the educator (Donaldson, 2013). Therefore, the study assessed the extent to which the teacher evaluation system at ICS measures teacher effectiveness and promotes improvement in critical thinking instructional practice.

Teacher collaboration. High levels of teacher collaboration both within and across content areas is positively associated with the adoption of innovative instructional strategies (Chong & Kong, 2012). Furthermore, the cohesiveness of collaborative networks is positively associated with the prevalence of progressive pedagogical beliefs among the network’s members (Bidwell & Yasumoto, 1999). Therefore, the study assessed the extent to which intradepartmental collaboration at ICS fosters the adoption of critical thinking pedagogy.

Data Collection Methods

Data collection. Quantitative data, collected via the administration of teacher and student surveys through Surveymonkey.com, provided evidence of the extent to which the different independent variables support the adoption of critical thinking instructional practices. In both surveys, the use of Likert scales allowed respondents to scale their responses to the survey items. The five-point scales measured the extent to which the respondent agreed or disagreed with statements relating to each of the variables.
Table 1

*Needs Assessment Variables and Data Sources*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Quantitative Data</th>
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<tbody>
<tr>
<td>Independent: Teacher Efficacy Beliefs (RQ1)</td>
<td>Teacher Survey</td>
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<tr>
<td>Independent: Pedagogical Beliefs (RQ 2)</td>
<td>Teacher Survey</td>
</tr>
<tr>
<td>Independent: Professional Development (RQ 3)</td>
<td>Teacher Survey</td>
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<tr>
<td>Independent: Teacher Evaluations (RQ 4)</td>
<td>Teacher Survey</td>
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<tr>
<td>Independent: Teacher Collaboration (RQ 5)</td>
<td>Teacher Survey</td>
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<tr>
<td>Dependent: Adoption of Critical Thinking Instructional Practices (RQ 6)</td>
<td>Student Survey</td>
</tr>
</tbody>
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*Teacher survey.* The teacher survey (Appendix B) included five sets of Likert-style questions (52 total) and five multiple-choice questions. Most of the Likert-style questions were adapted from existing instruments, while a few questions were developed by the researcher to be context-specific. The instruments were selected based on their reliability and availability of questions relating to the variables being investigated. Each set of Likert-style questions operationalized the independent variables and required the respondents to rate their response on a scale of 1 to 5, with 1 representing the lowest value score (*never*, *strongly disagree*, or *not at all true*) and 5 representing the highest value score (*always*, *strongly agree*, or *exactly true*). However, as discussed below, five of the questions required reverse coding, such that a response of 1 represented the highest value score and a response of 5 represented the lowest value score. The survey’s multiple-choice questions collected the respondents’ demographic data, including: the teacher’s subject area, licensure status, years of teaching experience, years of teaching at ICS, and the highest level of education completed (Appendix A).

*Research Question 1 – Teacher Efficacy Beliefs.* Survey section IA, “Teacher Self-Efficacy Beliefs,” measured the degree to which teachers feel confident about their individual job performance and instructional abilities. In this section, questions 1 through
4 were adapted from Schwarzer, Schmitz, and Daytner’s (1999) Teacher Self-Efficacy Scale, and questions 5 and 6 were developed by the researcher based on current research in critical thinking instruction (Abrami et al., 2015; Bai & Ertmer, 2008; Paul & Elder, 2001; Paul & Elder, 2002). Survey section IB, “Collective Self-Efficacy Beliefs,” measured the degree to which teachers’ confidence and efficacy are tied to the collective agency and cohesiveness of professional learning communities (e.g., departments). In this section, all questions (1 through 6) were adapted from Schwarzer, Schmitz, and Daytner’s (1999) Collective Self-Efficacy Scale. For both sections, responses to the 5-point scale ranged from not at all true (1) to exactly true (5).

Research Question 2 – Pedagogical Beliefs. Survey section II, “Pedagogical Beliefs,” measured the extent to which the teachers’ pedagogical beliefs are in alignment with evidence-based, student-centered practices that cultivate critical thinking skills. In this section, questions 1 through 12 were adapted from Isikoglu, Basturk, and Karaca’s (2009) study that investigated in-service teachers’ pedagogical beliefs regarding student-centered instruction. Isikoglu et al.’s (2009) survey provided questions highly relevant to this section of the study which examined the alignment of teachers’ pedagogical beliefs with student-centered practices. Questions 13 through 16 were developed by the researcher to provide additional questions pertaining specifically to evidence-based, critical thinking practices. For this section, responses to the 5-point scale ranged from strongly disagree (1) to strongly agree (5). However, questions 8, 10, 11, 12, and 13 required reverse coding because, for these questions only, a response of 1 indicated strong alignment of pedagogical beliefs with critical thinking instruction and a response of 5 indicated weak alignment of pedagogical beliefs with critical thinking instruction.
Research Question 3 – Professional development. Survey section III, “Professional Development,” measured the extent to which professional development opportunities at ICS prepare teachers with the knowledge and skills-sets to implement critical thinking instructional practices. In this section, questions 1 through 7 were adapted from the redesigned Standards Assessment Inventory (Denmark & Weaver, 2012), which provided relevant, Likert-style questions to scale teacher responses regarding their professional learning experiences. The researcher developed questions 8 through 10 to elicit additional responses about professional learning features pertaining specifically to critical thinking instruction. For this section, responses ranged from never (1) to always (5). An additional option, I don’t know (6), allowed respondents to refrain from providing a scaled response in the event they lacked adequate knowledge to do so.

Research Question 4 – Teacher Evaluations. Survey section IV, “Teacher Evaluations and Feedback,” assessed the degree to which the existing evaluation criteria promote improvement in teachers’ practice in the area of critical thinking instruction. Questions 1 through 3 were adapted from the redesigned Standards Assessment Inventory (Denmark & Weaver, 2012), and questions 4 through 9 were developed by the researcher to provide additional feedback on the effectiveness of the school’s evaluation system in fostering professional growth in critical thinking instruction. Questions provided by existing instruments were inadequate to fully operationalize this particular variable as it pertains to critical thinking instruction. Therefore, literature on effective teacher evaluation systems (Donaldson, 2013) informed the researcher’s development of survey questions 4 through 9. For this section, responses ranged from never (1) to always (5). An
additional option, *I don’t know* (6), allowed respondents to refrain from providing a scaled response in the event they lacked adequate knowledge to do so.

*Research Question 5 – Teacher Collaboration.* Survey section V, “Teacher Collaboration in Academic Departments,” measured the extent to which intradepartmental collaboration fosters teachers’ adoption of innovative instructional practices. All five of the survey questions in this section were adapted from the redesigned Standards Assessment Inventory (Denmark & Weaver, 2012). The questions selected from Denmark and Weaver’s (2012) inventory provide reliable indicators of faculty collaboration and its impact on the teachers’ professional practice. For this section, responses to the 5-point scale ranged from *never* (1) to *always* (5).

*Student survey.* The student survey (Appendix B) included two sections: Part I, “Instructional Practices,” and Part II, “Subject Area & Level”. Part I included 9 Likert-style questions, repeated four times (for a total of 36 questions) to operationalize the instructional practices that occur in the core subject areas of science, mathematics, English, and social studies. Formatting the survey in this manner permitted students to rate their teachers’ practices in each of the four subject areas. Responses to the 5-point Likert scale questions ranged from *never* (1) to *always* (5). An additional option, *not applicable* (6), was provided for items not relevant to the particular subject area. In Part I, questions 1 through 6 were adapted from University of Missouri’s Instructional Practices Survey (2007), while questions 7 through 9 were developed by the researcher based on current research in critical thinking instructional practices (Abrami et al., 2015; Elder & Paul, 2008). The University of Missouri (2007) instrument was selected based on its emphasis on student engagement and instructional practices that cultivate critical
thinking. Part II of the survey required students to indicate their current grade level and to select, from a list of options, their current science, mathematics, social studies, and English course and level.

Research Question 6 – Instructional Practices. Part I of the student survey served as an indicator of the dependent variable in this study: teachers’ adoption of critical thinking instructional practices. The survey questions assessed the effectiveness of the teachers’ practices and learning opportunities in their ability to promote students’ critical thinking development in the core subject areas. For each of the subject areas, students rated the extent to which they believe their teacher integrates practices that encourage (or discourage) critical thinking.

Data Analysis

Basic descriptive analyses of the teacher survey data revealed the mean response ratings for each of the variables. These ratings provided an indication of the extent to which each of the independent variables supports the teachers’ adoption of critical thinking instructional practices. Furthermore, basic descriptive analyses of the student survey data revealed the mean response ratings for the perceived instructional practices in each of the core subject areas (science, mathematics, social studies, and English). A comparison of the teacher survey data to the student survey data provided an indication of the extent to which the teacher responses align with the perceived instructional practices reported by students in each of the core subject areas.

In addition to the basic descriptive statistics, one-way analyses of variance (ANOVA) were performed with the teacher survey data to measure the variation between and within the teacher groups, defined by subject area, for each measured variable.
The one-way ANOVA tests allowed the researcher to compare the differences between the means across the four subject area groups: science, English, mathematics, and social studies. Because a thorough analysis of the data required the comparison of all four subject-area groups on each tested variable, the ANOVA test was selected over the similar t-test which only allows for the comparison of two groups (Salkind, 2014). Post hoc Bonferroni tests revealed the subject-area groups between which significant differences exist for each of the measured variables. While the ANOVA tests revealed the existence of significant differences across the subject-area groups, the Bonferroni comparisons provided the “significant pairwise difference” to which the significant difference across the groups could be attributed (Salkind, 2014, p. 248). The ANOVA and post hoc analyses permitted the researcher to determine the consistency of teacher responses across the core subject areas. In addition, the results informed the researcher of the relative effectiveness of ICS’ current school-wide reform initiative in supporting teachers’ transition to instructional practices that foster critical thinking development.

Findings

Teacher Surveys

Research Question 1 – Teacher Efficacy Beliefs

- According to basic descriptive analyses of the survey data, the teacher self-efficacy beliefs (total mean response score of 4.31; 4 = moderately true) and collective efficacy beliefs (total mean response score of 4.22; 4 = moderately true) suggest moderately high confidence among the teachers to adopt and enact innovative instructional practices.
Teacher Self-Efficacy Beliefs

- According to one-way ANOVA analyses, significant variation exists between and within groups (subject areas) for question 1 and question 3 (Appendix A).
  - Question 1: Post hoc Bonferroni tests revealed that significant variation exists between the science teachers and the mathematics teachers ($p = .005$) in their beliefs that they can exert a positive influence on both the personal and academic development of their students.
  - Question 3: Post hoc Bonferroni tests revealed that significant variation exists between the science teachers and the mathematics teachers ($p = .015$) in their beliefs in their ability to motivate students to participate in innovative projects.

Collective Efficacy Beliefs

- According to one-way ANOVA analyses, significant variation exists between and within groups (subject areas) for question 3 (Appendix A).
  - Question 3: Post hoc Bonferroni tests revealed that significant variation exists between the science teachers and the mathematics teachers ($p = .046$) in their beliefs about the faculty’s ability to work together to develop creative ways to improve the school environment.

Research Question 2 – Pedagogical Beliefs

- According to basic descriptive analyses of the pedagogical beliefs survey data, a total mean response score of 4.02 indicates that teachers, on average, somewhat agree with beliefs that support the adoption of critical thinking instructional practices. For this section of the survey, response options ranged from 1 (strongly
disagree) to 5 (strongly agree) to indicate the extent to which the respondents agree with practices that align with student-centered, critical thinking instruction. However, reverse coding was used on questions 10 – 13, such that responses closer to 1 indicated stronger agreement with student-centered pedagogical beliefs than did responses closer to 5. The mean response scores on questions 10 – 13 (Appendix A) suggest that teachers, on average, are neutral or somewhat agree with pedagogical beliefs that align with teacher-centered practices that are generally less effective than student-centered practices at cultivating critical thinking skills (Abrami et al., 2015; Elder & Paul, 2008).

- Question 10: A mean response score of 3.16 indicates that teachers are neutral in their belief that projects are more valuable when assigned after the students have learned the content.

- Question 11: A mean response score of 3.44 indicates that teachers are neutral or somewhat agree with the belief that the time required to deliver content to the students limits the class time that can be devoted to projects.

- Question 12: A mean value score of 3.15 indicates that teachers are neutral in their belief that class time is best utilized for the delivery of content material to the students.

- Question 13: A mean value score of 3.54 indicates that teachers are neutral or somewhat agree with the belief that a measure of successful teaching is the ability to impart knowledge to the students.

- According to one-way ANOVA analyses, significant variation exists between and within groups (subject areas) for questions 4, 5, 9 and 11 (Appendix A).
o Question 4: Post hoc Bonferroni tests revealed that significant variation exists between the social studies and the mathematics teachers (p = .036) and between the science and mathematics teachers (p = .021) in their beliefs that content subjects should provide students with hands-on learning opportunities.

o Question 5: Post hoc Bonferroni tests revealed that significant variation exists between the science teachers and the mathematics teachers (p = .043) in their beliefs that meaningful activities and projects are important elements of instruction.

o Question 9: Post hoc Bonferroni tests revealed that significant variation exists between the social studies and the mathematics teachers (p = .002), between the science teachers and the mathematics teachers (p = .031), and between the mathematics and English teachers (p = .015) in their beliefs that alternative assessments are valuable summative assessment options.

o Question 11: Post hoc Bonferroni tests revealed that significant variation exists between the English teachers and the mathematics teachers (p = .039) in their beliefs that the time required to deliver content to the students limits the class time that can be devoted to projects.

Research Question 3 – Professional Development

- According to basic descriptive analyses of the professional development survey data, a total mean response score of 3.19 indicated that teachers, on average, believe that professional development opportunities sometimes support their practice in the area of critical thinking instruction. However, an analysis of the
individual questions reveals several mean scores in the 2.7-2.9 range (2 = rarely and 3 = sometimes) on a 5-point scale (Appendix A).

- Question 3: A mean response score of 2.72 indicates that data are sometimes used to monitor the effectiveness of professional development opportunities.

- Question 4: A mean response score of 2.88 indicates that teachers are sometimes provided opportunities to evaluate professional development experiences in regards to their value and impact on student learning.

- Question 6: A mean response score of 2.94 indicates that student learning outcomes are sometimes used to determine the school’s professional development plan.

- Question 8: A mean response score of 2.83 indicates that professional development opportunities sometimes provide training in critical thinking instruction.

- Question 10: A mean response score of 2.76 indicates that professional development opportunities sometimes provide training in alternative assessment strategies that foster critical thinking development (e.g., Project Based Learning, portfolios, debates, etc.).

- One-way ANOVA analyses revealed significant variation (p = .044) between and within groups (subject areas) for question 5, suggesting significant differences exist between the teacher groups in their beliefs about the degree to which professional learning experiences are used to inform teaching practices. However,
post hoc Bonferroni tests revealed no pairwise significant difference (where p < .05) between the subject-area groups (Appendix A).

Research Question 4 – Teacher Evaluations

- According to basic descriptive analyses of the teacher evaluations survey data, a total mean response score of 3.27 indicates that the respondents, on average, believe that teacher evaluations sometimes support their ongoing growth and effectiveness in the implementation of critical thinking instructional practices. However, an analysis of individual questions revealed several mean scores in the 2.6-3.1 range (2 = rarely and 3 = sometimes) on a 5-point scale (Appendix A).
  - Question 1: A mean response score of 2.65 indicates that teachers rarely or sometimes provide colleagues with feedback intended to refine their implementation of instructional strategies.
  - Question 4: A mean response score of 3.09 indicates that teachers sometimes have a clear understanding of the evaluation criteria that are used to measure effectiveness in the classroom.
  - Question 7: A mean response score of 3.00 indicates that observation feedback sometimes provides suggestions for improving critical thinking instruction.
  - Question 8: A mean response score of 2.92 indicates that observation feedback sometimes provides suggestions for developing the students’ higher-order thinking skills.
Question 9: A mean response score of 2.84 indicates that evaluation feedback sometimes provides suggestions for projects or other alternative assessments for measuring student learning.

- One-way ANOVA analyses revealed significant variation (p = .04) between and within groups (subject areas) for question 3, suggesting significant differences exist between the teacher groups in their beliefs that all faculty members at ICS are held to high standards to increase student learning. However, post hoc Bonferroni tests revealed no pairwise significant difference (where p < .05) between the subject-area groups (Appendix A).

Research Question 5 – Teacher Collaboration

- According to basic descriptive analyses of the teacher collaboration survey data, a total mean response score of 3.57 indicated that teachers, on average, believe that faculty collaboration sometimes or often fosters the adoption of critical thinking instructional practices.

- According to one-way ANOVA analyses, no significant variation exists between or within groups (subject areas) for this portion of the teacher survey.

Student Surveys

Basic descriptive analyses of the student survey data revealed the mean response ratings for the perceived instructional practices in each of the core subject areas (science, mathematics, social studies, and English). Responses to the 5-point Likert scale questions ranged from never (1) to always (5), indicating the teacher’s lack of use (never) to frequent use (always) of student-centered practices that may foster critical thinking development. However, reverse coding was used on question 5 (“I learn the course
material through lectures provided by the teacher”), such that responses of 1 indicate frequent use (and responses of 5 indicate a lack of use) of student-centered practices that cultivate critical thinking. That is, student responses that indicate the teacher always uses lecture, a teacher-centered instructional practice, suggest that student-centered practices that cultivate critically thinking skills may be used less frequently.

Research Question 6 – Critical Thinking Instruction across the Curriculum

Part A: Science

- According to basic descriptive analyses of the Science survey data, a total mean response score of 3.83 (after reverse coding question 5) suggests that teachers often implement student-centered instructional practices that support critical thinking development. However, a mean response score of 4.06 on question 5 indicates that teachers often use lecture, a teacher-centered instructional practice, to present the course material to the students (Appendix A).

Part B: Mathematics

- According to the basic descriptive analyses of the Mathematics survey data, a total mean response score of 3.51 (after reverse coding question 5) suggests that teachers sometimes or often implement student-centered instructional practices that support critical thinking development. However, further analysis of each question revealed mean scores in the 2 – 3 range (2 = rarely and 3 = sometimes) on a 5-point scale (Appendix A).
  - Question 3: A mean response score of 3.11 indicated that teachers sometimes assign hands-on activities in class.
o Question 4: A mean response score of 2.18 indicated that teachers *rarely* assign projects or activities that require the students to work in teams.

o Question 5: A mean response score of 3.97 indicated that teachers *often* use lecture, a teacher-centered instructional practice, to present the course material to the students (reverse coded).

**Part C: English**

- According to the basic descriptive analyses of the English survey data, a total mean response score of 3.62 (after reverse coding question 5) suggests that teachers *sometimes* or *often* implement student-centered instructional practices that support critical thinking development. However, further analysis of each question revealed mean scores in the 2 – 3 range (2 = *rarely* and 3 = *sometimes*) on a 5-point scale (Appendix A).

  o Question 3: A mean response score of 3.46 indicated that teachers *sometimes* assign hands-on activities in class.

  o Question 5: A mean response score of 3.95 indicated that teachers *often* use lecture, a teacher-centered instructional practice, to present the course material to the students (reverse coded).

**Part D: Social Studies**

- According to the basic descriptive analyses of the Social Studies survey data, a total mean response score of 3.62 (after reverse coding question 5) suggests that teachers *sometimes* or *often* implement student-centered instructional practices that support critical thinking development. However, further analysis of each
question revealed mean scores in the 2 – 3 range (2 = rarely and 3 = sometimes) on a 5-point scale (Appendix A).

- Question 3: A mean response score of 3.30 indicated that teachers sometimes assign hands-on activities in class.
- Question 5: A mean response score of 4.45 indicated that teachers often use lecture to present the course material to the students (reverse coded).

**Study Limitations**

Study limitations existed due to the type and method of data collection used. Science teachers assisted with the administration of the study instruments by encouraging their students to complete the survey. Only some teachers offered incentives for their students to complete the survey. As a result, the respondents were unevenly distributed across the classes, with sophomores representing the greatest percentage of the student sample. Also, due to the incentives offered by these teachers, some science classes were more heavily represented than others. In addition, only quantitative data were collected in this study. The addition of qualitative data would have strengthened and provided a deeper understanding of the study results. While the quantitative data revealed the extent to which the variables are associated with current instructional practices, qualitative data would have provided greater insight into the school, teacher, and student factors associated with the problem of inadequate critical thinking development. Finally, the researcher’s role as Science Department Chair may have influenced the manner in which teachers, especially those in the Science Department, responded to the survey questions.
Discussion

According to needs assessment findings, there exist specific factors at ICS that hinder the adoption and implementation of critical thinking instructional practices. First, in reference to Research Question 3 (“How are teachers supported in the development of their professional practice in the area of critical thinking instruction?”), the data from the teacher surveys revealed several professional development features that could be targeted to enhance the teachers’ adoption of critical thinking instructional practices. In particular, the results indicated that data, including student learning outcomes and teacher feedback, are only sometimes used to monitor and inform professional development opportunities at ICS. Further, the results suggest that professional development opportunities at ICS may provide inadequate training in critical thinking instructional practices and alternative assessment strategies. Yet, effective professional development programs regularly use data to evaluate and inform teacher learning opportunities and provide ongoing training and support in a variety of instructional strategies (Desimone et al., 2002; Donaldson, 2013; Duzor, 2011). Further, the ANOVA analyses revealed significant variation between the mathematics and science teachers in the extent to which their teaching practices are informed by professional development experiences. Yet, effective teacher professional development programs promote the consistent transfer of the learned instructional strategies to the classroom context (Duzor, 2011). Therefore, in order to more effectively promote the adoption and transfer of critical thinking strategies, the study results were used to inform a professional development program that relies on teacher and student data to design and evaluate teacher learning opportunities, and that provides ongoing training in critical thinking instruction.
In addition to identifying professional development as a potential target for future reform initiatives, the analyses from the teacher surveys suggest that the current teacher evaluation system at ICS may inadequately support improvement in teacher practice in the area of critical thinking instruction. In reference to Research Question 4 (“How are teachers evaluated and supported in their ongoing growth and effectiveness in the implementation of critical thinking instructional practices?”), the results suggest that some teachers may lack sufficient understanding of the evaluation criteria or may receive insufficient feedback to foster improvement in their critical thinking instructional practice. Further, the ANOVA analyses revealed a high degree of variation in the extent to which teachers are held to high standards to increase student learning. Yet, teacher evaluations that provide ongoing and targeted feedback on instruction and concrete suggestions for improvement, while maintaining high expectations for student learning, encourage teachers’ professional growth (Donaldson, 2013). Therefore, in order to more effectively promote the adoption of critical thinking instruction, the study results were used to inform an intervention that provides teachers with ongoing feedback and support to foster their professional growth in critical thinking pedagogy.

In addition, in reference to Research Question 2 (“To what extent do teachers’ pedagogical beliefs align with evidence-based practices that cultivate students’ critical thinking skills?”), the study results suggest that teacher-centered pedagogical beliefs persist among many teachers at ICS. In particular, the mean response scores among questions that suggest lecture is the preferred mode of instruction, class time is best used for content delivery instead of project work, and the role of the teacher is to impart knowledge on the students, indicate a proclivity for teacher-centered beliefs. Further, the
ANOVA analyses revealed significant variation between the different subject areas in the extent to which the teachers’ pedagogical beliefs align with student-centered instructional practices. Yet, teachers’ consistent adherence to student-centered pedagogical beliefs often translates to the application of student-centered learning opportunities that, when compared to teacher-centered practices, more effectively foster critical thinking development (Abrami et al., 2015; Ertmer et al., 2012). Therefore, in order to promote the adoption of critical thinking instruction, the study results were used to inform an intervention that supports the teachers’ transition to a pedagogical belief system that aligns with student-centered practices.

In contrast to the study results that suggest the teachers’ pedagogical beliefs may inadequately align with student-centered practices that cultivate critical thinking, the results on teacher self- and collective efficacy beliefs (Research Question 1), and teacher collaboration (Research Question 5) more consistently favored the adoption of innovative instructional practices promoted by reform initiatives. However, the ANOVA analyses on teacher self-efficacy revealed significant variation between the different subject areas in the extent to which teachers believe they can exert a positive influence on their students and motivate their participation in innovative projects. Yet, teachers who successfully motivate their students to engage in innovative projects and problem-solving tasks more effectively cultivate their students’ critical thinking skills (Sungur & Tekkaya, 2006; Tiwari et al., 2006). In addition, the ANOVA analyses on collective efficacy revealed significant variation between the different subject areas in the extent to which teachers believe their team of faculty members can develop creative ways to improve the school environment. Yet, establishing and maintaining a positive school climate is critical to the
success of reform initiatives that encourage teachers’ adoption of innovative instructional practices (Chong & Kong, 2012; Leithwood & Jantzi, 2006; Lubienski et al., 2008a; Thoonen, Sleegers, Oort, Peetsma, & Geijsel, 2011). Therefore, an intervention that enhances teachers’ self- and collective efficacy beliefs may in turn enhance the school climate and thus the teachers’ motivation to adopt the promoted instructional practices.

Whereas the teacher survey data provided an indication of the degree to which the measured variables support the adoption of critical thinking instruction, in reference to Research Question 6 (“To what extent do teachers implement practices that support the development of students’ critical thinking skills?”), the student survey data revealed the extent to which critical thinking instructional practices occur in the core subject areas of science, mathematics, social studies, and English. According to the student survey results, teachers across the subject areas provide some opportunities for critical thinking development. However, in the mathematics and social studies classes, students reported infrequent integration of hands-on activities. Because hands-on activities often involve student engagement and content knowledge application to complete a task, they served as an indicator of critical thinking instruction. In addition, the students reported a lack of team-based learning activities in the mathematics classes. Again, because team-based activities often require student construction of knowledge and the application of their knowledge to solve problems, they served as a positive indicator of critical thinking instruction.

Most importantly, analyses of the student survey data revealed that teacher-centered practices, as evidenced by the frequent use of lecture to deliver content material, persist across the subject areas. However, instructional practices that place greater
emphasis on student engagement and authentic problem-solving, and less emphasis on lecture, more effectively develop students’ critical thinking skills (Abrami et al., 2015; Sungur & Tekkaya, 2006; Tiwari, et al., 2006). Furthermore, a comparison of the student data to the teacher data revealed a lack of agreement between the teachers’ pedagogical beliefs and their instructional practice. In contrast to the student survey data, analyses of the teacher survey data on pedagogical beliefs (total mean response score of 4.02) revealed that teachers, on average, generally adhere to student-centered beliefs that support the adoption of critical thinking instructional practices. Yet, according to the student data, teachers in all four of the tested subject areas often use lecture, a teacher-centered instructional practice, to deliver content to the students. In addition, upon closer examination of the teacher survey data on pedagogical beliefs, the mean response scores for questions 11 – 13 revealed a slight propensity for the delivery of content material to students, an instructional approach that reflects a greater adherence to teacher-centered beliefs. Therefore, the study findings support the need to develop an intervention that addresses key factors – namely professional development, teacher evaluations, and pedagogical beliefs – in order to promote the teachers’ adoption of student-centered instructional practices that more effectively foster critical thinking development.

**Conclusion**

This needs assessment study investigated the extent to which specific variables, including teacher self- and collective efficacy beliefs, pedagogical beliefs, professional development, teacher evaluations, and teacher collaboration, influence the adoption of critical thinking instructional practices within the core subject areas of science, mathematics, social studies, and English at an independent, private high school. In
addition, the study examined the extent to which instructional practices that cultivate critical thinking are implemented across the school’s core subject areas. Among the variables tested, the results revealed several professional development features that could be targeted to enhance the teachers’ adoption of critical thinking instructional practices. Furthermore, the results suggest that the current teacher evaluation system at ICS may inadequately support improvement in teacher practice in the area of critical thinking instruction. Finally, the results indicated that teacher-centered pedagogical beliefs, as reflected by teachers’ frequent use of lecture as a mode of content delivery, persist among many teachers at ICS. Therefore, the study results confirmed the need for an intervention that targets professional development, pedagogical beliefs, and/or teacher evaluations as avenues to promote the teachers’ adoption of critical thinking instructional practices.
Chapter 3

Rationale for Intervention

In a private, independent school context, an intervention that addresses the primary obstacles that hinder teachers’ adoption of student-centered instructional practices is necessary in order to enhance the development of students’ critical thinking skills. By targeting teachers’ pedagogical beliefs and professional growth, an intervention will positively influence students’ educational outcomes by promoting a transition to student-centered learning environments (Ertmer et al., 2012; Smith, 2000). According to the findings from the needs assessment study performed at ICS, the school’s professional development program was especially weak in supporting the high school teachers’ professional growth in the area of critical thinking instruction (Macek, 2015). Therefore, a professional development intervention that provides ongoing teacher support and feedback (Donaldson, 2013), encourages teacher collaboration and reflection (Belvis et al., 2013; Chong & Kong, 2012), and models student-centered learning strategies (Garet et al., 2001) was designed to promote the teachers’ adoption of student-centered practices and, in turn, the students’ development of critical thinking skills (Abrami et al., 2015).

This literature review examines research that informed an intervention targeting teachers’ professional practice, a primary factor that influences the development of students’ critical thinking skills. In order to uncover research that informs an intervention targeting teachers’ practice in the area of critical thinking instruction, education databases, including EBSCOhost and JSTOR, were explored using the following search terms: “critical thinking,” “professional development,” “teacher beliefs,” “instruction,” “cognitive apprenticeship,” “constructivist theory” “student-centered,” “problem-based
learning,” and “inquiry based learning”. Literature included for consideration provided insight into professional development and critical thinking instructional strategies in secondary and higher education, with research focusing on science education and reform receiving greater emphasis. In addition, only scholarly, peer-reviewed research from the past 15 years was included in the database searches. Literature excluded from the database searches focused on elementary education and professional development situated in non-educational fields (e.g., healthcare, business, etc.). Ultimately, through an in-depth exploration of recent education literature and the application of current theory in professional learning and cognitive development, this literature review served to inform a professional development intervention that effectively targets science teachers’ practice in the area of critical thinking instruction in private schools.

**Theoretical Framework**

There exist multiple theoretical perspectives that elucidate the complex nature of learning and support knowledge development and application in various educational and professional settings. Among these are constructivism and related versions of this paradigm including cognitive apprenticeship, a theoretical model within the situated learning perspective (Brown et al., 1989; Cobb & Bowers, 1999; Stewart & Lagowski, 2003). The cognitive apprenticeship model provides a theoretical framework for the development of programs that support teachers’ learning and professional growth.

**Cognitive Apprenticeship Theory**

The cognitive apprenticeship theory, inspired by traditional apprenticeship models used to develop expertise in skilled trades, supports learning via collaborative problem-solving within authentic social and cultural contexts (Stewart & Lagowski, 2003). By
enculturating learners within authentic problem-solving contexts, cognitive apprenticeship models positively influence learners’ belief systems and expertise development via modeling, coaching, expert feedback, social interaction, and reflection (Collins, Brown, & Newman, 1989; Stewart & Lagowski, 2003). In particular, cognitive apprenticeship approaches intentionally guide the learning process through the sequential incorporation of four cognitive, or intellectual, dimensions: content, method, sequence, and sociology (Collins et al., 1989).

As a pedagogical model, cognitive apprenticeship theory informs instruction and learning in educational settings through the incorporation of these four cognitive dimensions (Collins et al., 1989; Stewart & Lagowski, 2003). As learners proceed through the content dimension, they develop the requisite domain knowledge and acquire strategies for learning and performing the various tasks inherent to the given subject area or discipline. During the method dimension, the learner experiences significant growth through modeling and coaching by an expert in the field, articulating and reflecting on his knowledge and problem-solving strategies, and exploring novel strategies for independently solving problems in the field. Of particular interest in this dimension is the coaching component; through the use of “scaffolding” followed by “fading,” the coach or instructor guides the learner by first providing and then decreasing the structures in place to support the learner’s performance (Stewart & Lagowski, 2003). Following the method dimension, the sequence dimension involves the development of the learner’s skills and expertise through the performance of authentic tasks of increasing complexity and diversity. Finally, during the sociology dimension, the instructor guides learners towards the desired level of expertise by providing an authentic learning environment in which
the learners take on the role of expert, actively collaborating with one another and applying their acquired knowledge to solve complex problems and achieve the established goals. Ultimately, through the sequential implementation of the four cognitive dimensions, the instructor guides the learners towards expertise by enculturating them in an authentic learning environment that positively influences their belief system, knowledge acquisition, motivation, and problem-solving abilities (Collins et al., 1989; Stewart & Lagowski, 2003).

Applied to professional development frameworks, cognitive apprenticeship theory provides a promising approach to promoting teacher-level change, particularly in the area of critical thinking instruction. In reviewing the literature on promoting teacher-level change through education reform initiatives, several key themes emerged. In particular, initiatives that promote reform-oriented instruction require teachers to transition their pedagogical belief system from one that aligns with traditional, teacher-centered practices to one that embraces innovative, student-centered approaches (Stipek, Givvin, Salmon, & MacGyvers, 2001). The need for this transition in pedagogical beliefs is supported by research that suggests that teachers who adopt student-centered pedagogical beliefs frequently implement innovative, student-centered pedagogical practices (Ertmer et al., 2012). Shifting the classroom focus from a teacher-centered to a student-centered learning environment, in turn, improves student outcomes, including critical thinking and problem solving abilities (Abrami et al., 2015; Holt, Young, Keetch, Larsen, & Mollner, 2015).
Constructivist Learning Theory

Student-centered instructional practices that align with constructivist learning theories promote deeper learning and cognitive skill development by encouraging students to actively engage in the learning process (Baeten, Struyven, & Dochy, 2013; Pegrum, Bartle, & Longnecker, 2015; Spector, 2014). In particular, student-centered instructional practices are those that: encourage students to construct their own understanding of concepts, involve the teacher as a facilitator and coach in the learning process, and require the application of knowledge to real-world problems and case studies (Baeten et al., 2013). According to Piaget’s (1970) theory of cognitive development, learners must progress through four cognitive stages (Sensorimotor, Preoperational, Concrete Operational, and Formal Operational) in order to develop higher-order thinking skills and effectively apply them to real-world problems. In particular, students must reach the Formal Operational stage, or “stage 4,” of cognition in order to think critically about abstract principles and solve complex problems (Paul & Elder, 2001; Pinkney & Shaughnessy, 2013). The Formal Operational stage of cognition is characterized by the use of advanced analytical skills such as inductive and deductive reasoning to solve complex problems (Paul & Elder, 2001).

Effective student-centered, constructivist practices encourage the learners’ progression to higher stages of cognition by promoting a degree of disequilibrium while challenging them to assimilate and apply their knowledge to novel contexts (Pinkney & Shaughnessy, 2013). Placed at the center of learning, students become creators of their knowledge, actively developing their skills and understanding of concepts (Pegrum et al., 2015; Spector, 2014). In particular, constructivist learning strategies that actively engage
students in challenging, authentic problem-solving experiences that reside within the students’ “regime of competence” (p. 19) promote higher-order cognitive development (Gee, 2004). Similarly, in social constructivism, students who work within their “zone of proximal development” while collaborating with peers and mentors to develop their knowledge and solve complex problems experience gains in cognitive development and higher-order thinking abilities (Vygotsky, 1978). Students progress through their zone of proximal development when provided with complex problems appropriate for their stage of cognitive development and assisted by more knowledgeable peers or experts on the given topic. In turn, students construct their knowledge on the topic while advancing to higher stages of cognition (Pinkney & Shaughnessy, 2013). Therefore, according to constructivist learning theories, critical thinking skills are best developed when learning is situated within an authentic, real-world context and provides students with ample opportunities for collaboration with one another and experts in the field of interest (Gee, 2008; Resnick, 1987).

A pedagogical approach related to the constructivism paradigm, cognitive apprenticeship theory supports student learning through active collaboration with and guidance provided by a mentor or expert in an authentic setting. Applied to a professional development framework, a cognitive apprenticeship approach places the teacher participants in the role of student, or “apprentice,” and the professional development instructor in the roles of mentor, expert, and coach. This learner-centered approach to professional development in many ways models research-based, constructivist practices for cultivating students’ critical thinking development. As such, the cognitive apprenticeship framework serves not only to develop pedagogical expertise among the
apprentices (teachers), but also to model an effective approach for fostering learners’ critical thinking development. Ultimately, as the teacher participants, or apprentices, progress through the content, methods, sequence, and sociology dimensions of the cognitive apprenticeship professional development model (Collins et al., 1989), they learn to become expert practitioners in cultivating their own students’ critical thinking skills.

Figure 2

*Cognitive Apprenticeship Theory as a Model for the Professional Development Framework*

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**Literature Review: Cultivating Critical Thinking Skills**

Using the cognitive apprenticeship theory as a foundation, an effective professional development intervention that targets teacher instruction will provide the teacher participants with the requisite knowledge and strategies for fostering students’ critical thinking development. The literature provides numerous different approaches, supported by constructivist learning theories, which effectively cultivate students’ critical thinking skills, more simply defined as higher-order cognitive skills (Holt et al., 2015). Examples of research-based critical thinking approaches include: implementing engaging, student-centered instructional practices such as problem- and inquiry-based learning; designing assessments that include higher-order cognitive questions; and,
aligning higher-order learning objectives with classroom instruction and assessments (Abrami et al., 2015; Holt et al., 2015; Marshall & Horton, 2015; Sungur & Tekkaya, 2006).

Recent studies examine and compare the effectiveness of different instructional approaches that target critical thinking development (Abrami et al., 2015; Holt et al., 2015; Pinkney & Shaughnessy, 2013). For instance, in their recent study, Holt et al. (2015) investigated the interactive effect of student-centered instruction, assessments, and classroom alignment on students’ critical thinking gains over time. The sample population included 1114 students enrolled in one of fifteen sections of an undergraduate biology course, and the nine instructors that taught the course sections. The biology courses remained un-manipulated as the researchers performed multiple observations of each of the fifteen sections during both the first and second semesters. In addition, the researchers administered voluntary, online student surveys during the first and last week of each semester. Using the Bloom’s Taxonomy of Learning skills listed in levels three and above (Bloom, 1956), the researchers designed the survey instrument to include content-related free-response and multiple choice questions that would evaluate the students’ higher-order cognitive skills.

In addition, Holt et al. (2015) collected various classroom artifacts, such as syllabi and tests, in order to evaluate the cognitive level of, and the alignment between, course assessments and learning objectives. The researchers used Bloom’s Taxonomy of Learning to rate, on a scale of one to six (to correspond with Bloom’s levels), the cognitive level of the biology assessments and learning objectives. These “Bloom scores” were then used to calculate the alignment scores by subtracting the assessment score from
the learning objective score, such that a score of zero indicated perfect alignment. Furthermore, the researchers observed 86 recorded classroom lessons and evaluated the instructors using the Reformed Teaching Observation Protocol (RTOP), a “validated and reliable quantitative method to evaluate the learner-centeredness of instruction” (Holt et al., 2015, p. 7). The researchers then averaged the RTOP scores for each section; each score corresponded to one of the five RTOP levels, with “strictly teacher-centered lecture” represented by level I and “complete learner-centeredness; involves critique, open-ended inquiry, hypotheses, and critical reflection” represented by level V (Holt et al., 2015, p. 7). The instructors’ RTOP scores, in addition to the alignment and Bloom scores for each section, served as the independent variables while the students’ post-quiz scores served as the dependent variable. The researchers used ANCOVA models to determine the role of each of the independent variables in influencing students’ post-quiz scores.

The results of Holt et al.’s (2015) groundbreaking study, the first to investigate the interaction of all of the aforementioned independent variables on students’ critical thinking gains, revealed that teacher observation scores corresponding to RTOP level III (“learner-centered” classroom), when compared to RTOP level I (p = 0.04) and RTOP level II (p = 0.08) (both “teacher-centered” classrooms), produced observable gains in students’ cognitive skills on the biology post-quiz. However, according to the Tukey-Kramer post hoc analysis, there exists no significant difference (p = 0.22) between RTOP level I and RTOP level II in their effect on students’ cognitive gains (Holt et al., 2015). In addition, according to regression analyses, the teacher RTOP level (p = 0.04) explained the significant variation in post-quiz scores, with a 7-point increase in RTOP scores.
producing a 9% increase on students’ post-quiz scores, and a 14-point increase in RTOP scores (equating to one RTOP level) producing a 19% increase on students’ post-quiz scores (Holt et al., 2015). Furthermore, ANCOVA analyses revealed that neither the Bloom scores (learning objective Bloom scores: p = 0.31; assessment Bloom scores: p = 0.38) nor the alignment scores (p = 0.38) significantly influenced students’ post-quiz scores (Holt et al., 2015).

Because RTOP level III was the highest score reported for the instructors, further research is needed to determine the degree to which higher RTOP levels impact students’ critical thinking gains. However, the findings of Holt et al.’s (2015) study elucidate the positive impact of a student-centered learning environment on cultivating students’ critical thinking skills. In addition to revealing a strong positive association between RTOP level III (learner-centered classroom) and students’ critical thinking gains, the findings suggest that instruction plays a more profound role than learning objectives, assessments, and curricular alignment in promoting the students’ higher-order cognitive development (Holt et al., 2015). Therefore, in order to best support students’ cognitive development, the professional development intervention was designed to provide the participants with the knowledge and skill-sets needed to effectively implement student-centered instructional strategies that cultivate critical thinking skills.

**Student-Centered Instructional Practices**

Recent research, such as that performed by Holt et al. (2015), provides compelling evidence in support of a transition from traditional, teacher-centered to innovative, student-centered instructional practices in order to foster students’ critical thinking development. Student-centered practices must be carefully selected and
strategically implemented in order to effectively promote students’ critical thinking development. For instance, students who both express their knowledge via oral or written dialogue and participate in authentic learning experiences cultivate their critical thinking skills (Abrami et al., 2015). There exist many types of dialogue that support critical thinking development, including: student dyads, whole-class and small-group discussions, formal debates, and Socratic dialogue (Abrami et al., 2015). Similarly, there exist different authentic (real-world) learning approaches that promote critical thinking development, including: problem-based learning, inquiry-based learning, gaming, and role-playing (Abrami et al., 2015; Marshall & Horton, 2015; Sungur & Tekkaya, 2006). As supported by constructivist learning theories, students experience measurable gains in critical thinking development when they learn in an environment that combines dialogue, authentic learning activities, and mentoring by the teacher or other experts in the field (Abrami et al., 2015; Collins et al., 1989).

Problem-based learning. Constructivist learning theories, in particular situated learning and cognitive apprenticeship theory, encourage the enculturation of students within authentic, real-world contexts in order to foster problem-solving and cognitive development (Brown et al., 1989; Collins et al., 1989; Lave & Wenger, 1991). Problem-based learning (PBL) is an example of an authentic, student-centered learning approach that is positively associated with students’ critical thinking development. In PBL, students work collaboratively to solve complex problems in real-world contexts (Sungur & Tekkaya, 2006). In this constructivist, student-centered learning approach, the teacher serves to facilitate the learning process while the students research and explore solutions to ill-structured problems (Sungur & Tekkaya, 2006). Ill-structured problems are
complex problems that have multiple solutions and provide limited information to students for solving them (Wheeler et al., 2005). Students who actively engage in PBL demonstrate enhanced development of critical thinking skills and disposition, both essential elements of critical thinking (Sungur & Tekkaya, 2006; Tiwari et al., 2006).

In their study of self-regulation determinants, Sungur and Tekkaya, (2006) indirectly revealed the effects of PBL on students’ critical thinking development. The researchers used a quasi-experimental design to investigate the effects of problem-based versus traditional learning environments on students’ self-motivation and use of learning strategies, both essential components of self-regulation. Sixty-one high school biology students, divided into an experimental group and a control group, learned the course material via solving ill-structured problems (treatment group) or via traditional, textbook-oriented instruction (control group). Following the treatment, the students in each group completed the self-reported Motivated Strategies for Learning Questionnaire (MSLQ), which included sections for motivation and learning strategies, to determine the extent of self-regulation development. MANOVA analyses of the student responses revealed that PBL, when compared to teacher-centered, textbook-oriented instruction, was positively associated with students’ self-motivation and use of learning strategies. In particular, the results of Sungur and Tekkaya’s (2006) study indicated that critical thinking, one of the measured learning strategies, significantly improved in the PBL group (p = 0.002).

In a similar study, Tiwari et al. (2006) investigated the effects of PBL versus lecture on students’ critical thinking disposition. The participants, 79 first-year, undergraduate nursing students, were randomly assigned to a class taught either via lecture or PBL. Using a mixed-methods approach, the researchers investigated the
participants’ critical thinking disposition development during the one-year course and for two years thereafter. Quantitative data, collected at four time points, included students’ pre- and post-test scores on the California Critical Thinking Disposition Inventory (Facione & Facione, 1994). Qualitative data from semi-structured interviews provided in-depth accounts of students’ perceptions and feelings about their learning experiences. The findings indicated that students in the PBL environment, when compared to students in the lecture environment, experienced significantly greater gains in the critical thinking disposition measures of truth-seeking, analyticity, systematicity, and critical thinking self-confidence over the three-year time period. Importantly, the longitudinal nature of the study revealed the long-term implications of PBL on students’ critical thinking development (Tiwari et al., 2006).

Inquiry-based learning. In alignment with constructivist learning theories, inquiry-based learning is another example of an authentic, student-centered learning approach that, when implemented effectively, positively influences students’ critical thinking development (Franco, 2013; Ku, Ho, Hau, & Lai, 2014; Marshall & Horton, 2011). While many different models of inquiry-based instruction exist, all of the models encourage students to perform within their zone of proximal development (Vygotsky, 1978), applying their prior knowledge and higher-order thinking skills to solve complex problems (Ku et al., 2014; Marshall & Horton, 2011). In addition, inquiry-based models encourage students to deeply learn concepts, not simply memorize them (Franco, 2013; Marshall & Horton, 2011). Most inquiry models consist of the following components: Engage, Explore, Explain, and Extend (Franco, 2013; Marshall & Horton, 2011). The effective implementation of inquiry-based learning investigations requires teachers to
shift their central role to one of facilitator, guiding students through the four components of the inquiry process by asking thoughtful and probing questions that activate higher-order thinking and deep conceptual understanding (Franco, 2013; Ku et al., 2014; Marshall & Horton, 2011).

In their recent study, Marshall and Horton (2011) investigated the effects of inquiry-based learning on students’ use of higher-order cognitive skills, including critical thinking. In particular, the researchers examined the teacher participants’ use of the Explore and Explain inquiry components and their effect on the level of cognition required of students to perform these components. Using the Electronic Quality of Inquiry Protocol (EQUIP) observation instrument, the researchers performed 102 full-length observations of the 22 teacher participants, including 12 science and 10 mathematics teachers (Marshall & Horton, 2011). The EQUIP observation instrument measures 19 different indicators relating to the inquiry process. For the purpose of this study, the researchers focused on the following two indicators: “Cognitive Level” of students and “Component of Inquiry” being investigated. The researchers also used the “Order of Instruction” indicator, focusing on the extent to which the teachers have their students explore concepts prior to explaining them, to divide teachers into a higher-performing group (lessons given a Level 3 or 4 rating) and a lower-performing group (lessons given a Level 1 or 2 rating). The researchers then performed Z-tests to compare each of the teacher groups with the “Cognitive Level” and “Component of Inquiry” variables. They performed additional analyses of the Explore and Explain “Component of Inquiry” to identify correlations, using Pearson’s r, between the amount of class time
devoted to the Explore and Explain components and to activities requiring students to apply higher- versus lower-order levels of cognition.

The results of Marshall and Horton’s (2011) study revealed a strong positive association between the amount of time devoted to the Explore and Explain components of inquiry and the students’ application of higher-order cognitive levels. In particular, in lessons that earned a level 3 or 4 rating, teachers allotted 57% of the class time to facilitating higher-order cognitive levels with their students, in comparison to lessons that earned a level 1 or 2 rating in which teachers only allotted 23.2% of class time to facilitating the students’ higher-order cognitive levels. In general, the amount of time allotted to student explorations significantly (p < .001) and positively correlated to the amount of time that students were engaged in activities that required the application of higher-order cognitive levels (Marshall & Horton, 2011). In addition, the results revealed a significant, negative correlation between the time allotted to explanation and students’ use of higher-order cognitive levels. Overall, when compared to the observed non-inquiry lessons, the inquiry-based lessons allotted significantly more class time to higher- versus lower-order levels of thinking.

The study performed by Marshall and Horton (2011) supports the use of inquiry-based learning approaches to foster students’ critical thinking development. In particular, inquiry-based lessons that place concept exploration activities prior to the explanation component more effectively support students’ deep learning of content and critical thinking development (Marshall & Horton, 2011). The findings also support the need for teachers to transition from teacher-centered to teacher-facilitated instructional practices in which they guide and support students as they develop their own understanding of
concepts. In Marshall and Horton’s (2011) study, as the time teachers allotted to explaining material increased (via lecture, for example), the amount of time students’ applied higher-order cognitive levels decreased. Therefore, when adequate emphasis is placed on allowing students to explore concepts, inquiry-based learning serves as an effective, student-centered learning strategy that promotes the students’ application and development of critical thinking skills (Marshall & Horton, 2011).

Students who learn in primarily student-centered environments, especially those that combine authentic learning, dialogue, and mentoring by teachers or experts, experience significant gains in critical thinking development (Abrami et al., 2015). In particular, students who actively engage in problem-based and inquiry-based learning environments participate in authentic, hands-on activities; apply their knowledge to solve complex, real-world problems; and, in turn, experience significant gains in critical thinking skill development (ÇORLU & ÇORLU, 2012; Marshall & Horton, 2011; Sungur & Tekkaya, 2006; Tiwari et al., 2006). Therefore, an effective cognitive apprenticeship model of professional development will incorporate within the methods dimension opportunities for the mentor to model the aforementioned student-centered strategies and for the teacher apprentices to reflect upon their acquired knowledge and skill-sets in critical thinking instruction.

**Building Teachers’ Capacity for Change**

In order to effectively produce change in teachers’ instructional practice, a professional development intervention must take into account the school’s culture and the pedagogical beliefs to which most of the teachers adhere. The idea of enculturation, as supported by situated learning and cognitive apprenticeship theories, pertains as well to
professional development initiatives; in order for teachers to learn and effectively apply the promoted instructional strategies in a manner that enhances critical thinking development, their learning must be situated within the cultural context in which the strategies are to be implemented (Brown et al., 1989; Stewart & Lagowski, 2003). Therefore, a primary goal of the intervention was to develop a culture that embraces learning and professional growth for the purpose of enhancing student outcomes. Ultimately, teachers who actively engage in learning opportunities within a culture that values professional growth and innovative instruction are more likely to transition their pedagogical belief system to one that embraces student-centered learning (Brown et al., 1989). Furthermore, a cognitive apprenticeship professional development model that embraces the culture of autonomy to which independent school educators are accustomed, while encouraging teacher collaboration and participation in instructional decision-making processes, will build the teachers’ capacity for meaningful change (Donaldson, 2013; Rhodes, Camic, Milburn, & Lowe, 2009).

**Teacher autonomy and collaboration.** The effectiveness of a professional development intervention in independent schools is dependent upon numerous school factors, including the program’s framework, the school culture, teacher motivation, and school leadership practices (Desimone et al., 2002; Donaldson, 2013; Thoonen et al., 2011). A school culture that embraces community, collaboration, and professional learning is more likely to adopt initiatives promoted by a professional development program (Donaldson, 2013; Lave & Wenger, 1991; Rhodes et al., 2009). In independent schools where autonomy is commonly valued by the school culture, teachers under increased pressure for reform may resist initiatives intended to change their practice

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(Bidwell & Dreeben, 2003; Robinson & Timperley, 2007). However, the same autonomy that hinders the effectiveness of reform efforts may, conversely, improve intervention outcomes when exercised by teachers in collegial networks (Yasumoto, Uekawa, & Bidwell, 2001). As opposed to reform efforts that undermine autonomy by imposing change upon teachers, teacher-led initiatives that encourage collaboration and problem-solving within learning communities produce improved outcomes (Lave & Wenger, 1991; Rhodes et al., 2009; Robinson & Timperley, 2007).

Teachers given the opportunity to exercise their autonomy in the process of sense-making develop a deeper understanding of educational problems and the implementation measures needed to address them (Spillane, Reiser, & Reimer, 2002). Their cognitive interpretation of the change initiative depends greatly on their prior experiences, knowledge, and value-system, and is further constructed through collaboration in professional learning communities (Spillane et al., 2002). As the agents of change in reform initiatives, teachers given ample time to engage in sense-making within a learning community more effectively interpret the basis of reform initiatives and develop innovative solutions to improve instruction and student outcomes (Spillane et al., 2002). Thus, during times of change, teachers encouraged to exercise their autonomy through the collective cognitive process of sense-making exhibit changes in knowledge and behavior that positively influence their practice (Spillane et al., 2002).

Robinson’s (2012) small-scale, qualitative study investigated the role of collegial relationships on teachers’ professional agency, an important autonomous attribute, during times of educational reform. Robinson (2012) defines professional agency as the capacity of individuals to act under changing conditions. When policy decisions are imposed upon
teachers, the subsequent loss of autonomy stifles their motivation to adopt the reform initiatives (Bidwell & Dreeben, 2003). Conversely, as supported by research on the benefits of communities of practice (Lave & Wenger, 1991), Robinson (2012) argues that teachers are more likely to construct agency, or effectively adapt to the reform initiatives, when they work collaboratively in supportive, collegial networks to navigate the change process. An Australian non-government (independent) school undergoing educational reform provided the site for the study (Robinson, 2012). Robinson (2012) selected this site in order to investigate the degree to which the teachers constructed professional agency in response to a reform initiative that required them to respond to increasing and conflicting demands imposed upon the school by the state and Federal government. Using an ethnographic approach, Robinson (2012) observed the study participants, including a principal and 24 teachers and their teaching assistants, to determine the effects of the change process on their professional agency. Analyses of the in-depth, qualitative data, collected from observations and semi-structured interviews with the participants, confirmed Robinson’s (2012) hypothesis that teachers construct professional agency when they work collaboratively to adapt to policy changes. While some participants initially expressed concern over the perceived loss of autonomy from the policy imposed upon them, their negotiation of the change process within a collegial network led them to construct professional agency and thus adopt the promoted practices (Robinson, 2012). These findings reinforce the importance of teacher collaboration as a means of leveraging, as opposed to suppressing, autonomy in the form of professional agency during times of educational reform.
Rhodes et al.’s (2009) study on teacher-centered change further supports the implementation of educational interventions that embrace, rather than undermine, teacher autonomy. Their study expands upon findings from recent research that suggests school leaders who involve teachers in decision-making processes produce improved educational outcomes when compared to leaders who fail to encourage teacher participation in curricular decisions (Vroom, 2003). Rhodes et al. (2009) hypothesized that collaborative, teacher-led interventions improve school climate and teacher-principal relationships, and thus enhance educational outcomes. Their 5-year intervention, called the “Teacher Empowerment Project,” included five Midwestern middle schools, three of which received the treatment protocol and two of which served as non-treatment models for comparison. In the treatment schools, teachers worked collaboratively to diagnose problems and select interventions to improve school climate. “Teacher Working Groups” presented intervention proposals and, upon approval by the administration, developed implementation plans and goals (Rhodes et al., 2009).

Rhodes et al. (2009) utilized a mixed-methodology approach to collect extensive data from 180 teachers and approximately 3,000 students from the five schools participating in the “Teacher Empowerment Project”. Annual administration of student and teacher surveys provided quantitative data, and student and teacher interviews, participant observations, and various school artifacts provided in-depth qualitative data. Statistical analyses of the teacher data indicated that the teacher empowerment intervention successfully involved teachers in the change process, and improved school climate and teacher-principal relations. Analyses of student data further revealed an indirect, positive impact of the intervention on student performance indicators (Rhodes et
al., 2009). Therefore, teacher-led interventions in which teachers exercise their autonomy in collaborative, decision-making processes promote enhanced school and educational outcomes (Rhodes et al., 2009).

Yasumoto et al.’s (2001) study further supports teacher collaboration as an essential ingredient to the success of school reform initiatives. In their study, the researchers explored the impact of faculty collegial networks on students’ academic achievement growth. They argue that collegial networks are most likely to form within the specialized subject areas, with stronger ties leading to enhanced problem-solving abilities by the group’s members. The researchers examined faculty subgroups within mathematics and science departments at 52 public high schools and used hierarchical growth models to analyze the effect of collegial networks on student academic achievement gains over time. The results, which indicate that stronger collegial networks intensify the effects on student achievement gains, are highly important for educational leaders to consider when seeking to improve student outcomes. According to the findings, teachers encouraged to work as collective units effectively diagnose educational problems and implement practices that successfully enhance student achievement (Yasumoto et al., 2001). Therefore, initiatives that empower teachers to leverage their autonomy to collectively solve subject-based educational problems are worth considering when designing interventions to improve student learning outcomes.

**Professional development.** Designed with the intention of improving teacher productivity, professional development programs serve as a primary vehicle for influencing change in teacher’s professional practice. The literature provides multiple professional development frameworks that produce varying results depending on factors
such as the type of professional learning in which educators engage, the planning process, and the alignment of the professional development activities with the learning objectives (Garet et al., 2001; Guskey, 2014). Research designs and confounding variables limit the ability of researchers to effectively identify professional development features that consistently produce teacher-level change that leads to enhanced student outcomes (Garet et al., 2001). Desimone et al. (2002) addressed this gap in the literature by conducting an extensive 3-year, longitudinal study of teacher change. Analyses of quantitative survey data, collected three times from more than 200 teachers from 30 schools, revealed the frequency with which participation in a particular professional development activity translated into changes in mathematics and science teaching practices. Combining the longitudinal results with the cross-sectional data collected from their previous national study (Garet et al., 2001) permitted an in-depth analysis to inform professional development policy decisions.

Desimone et al.’s (2002) findings provide specific professional development features that most frequently produce change in teacher practice. First, professional development that includes training in specific instructional practices promotes teachers’ application of those practices. In addition, professional development programs that incorporate training in the use of higher-order instruction and alternative assessment practices are most likely to promote change in teacher practice. Finally, professional development programs that encourage collective learning and coherence, or building on teachers’ expertise, produce positive outcomes. Therefore, professional development interventions that incorporate the characteristics suggested by Desimone et al.’s (2002)
findings may positively influence teachers’ adoption of the promoted critical thinking practices.

In combination with the features recommended by Desimone et al.’s (2002) study, professional development frameworks that encourage educators to reflect on their teaching practices may further enhance the effectiveness of the intervention. In order to be effective, professional development must not only educate faculty on critical thinking instructional practices, but it must also ensure the successful transfer of these practices to the classroom context (Belvis et al., 2013; Duzor, 2011). In their study, Belvis et al. (2013) examined the Teacher Education Program for Teaching Mathematics in order to identify professional development features that promote the transfer of learned practices to the classroom. Participants in the program, 284 primary and secondary education teachers, worked collaboratively to reflect upon their practice and develop strategies that incorporate active and cooperative learning, problem-solving, and technology to improve student learning outcomes. Using a mixed-methodology approach, Belvis et al. (2013) collected both quantitative and qualitative data to evaluate the effectiveness of the mathematics training program in improving teacher and student outcomes. Quantitative data collected from the administration of an adapted version of the Holistic Model, an evaluation framework that assesses the educators’ satisfaction with the program, provided insight into the participants’ level of learning, transfer to the classroom, and impact of the novel pedagogy on student achievement. Qualitative data collected from interviews with participants provided in-depth feedback regarding their level of learning and the conditions that influenced the effective transfer of learned practices to the classroom (Belvis et al., 2013).
The results of Belvis et al.’s (2013) study indicated that 71% of participants perceived the level of learning as sufficient, with an emphasis on the need for additional learning time to further develop their level of comfort with the practices. Furthermore, 81.3% of participants reported the successful transfer of learned practices to the mathematics classroom. The participants acknowledged the need for additional in-depth training and ongoing mentor support to improve the implementation of the learned practices and the continued adherence to the program’s goals. Therefore, given adequate training time and support, collaborative, reflective practice integrated into a professional development intervention may promote teachers’ learning and transfer of the learned practices to the classroom context (Belvis et al., 2013).

**Reflective practice.** Thoonen et al. (2011) further investigated the effects of reflection, in addition to teacher motivation, school conditions, teacher learning, and leadership practices, on changes in teachers’ practice. The researchers acknowledged the numerous challenges associated with producing school-wide change and thus the need to cultivate the teachers’ capacity for learning using a systems-level approach. To measure the effects of the constraining factors of teacher motivation, capacity for learning, professional development, and leadership approaches on teacher practice, Thoonen et al. (2011) designed a model, adapted from an existing framework (Leithwood, Jantzi, & Mascall, 2002), to identify relationships between these constructs. Study participants, including 502 teachers from 32 elementary schools in the Netherlands, completed a survey administered as part of a school improvement initiative.

Statistical analyses of the quantitative data collected from the teacher surveys revealed the relationship between the identified constructs and teacher practice (Thoonen
et al., 2011). First, similar to Belvis et al.’s (2013) findings, the results indicated that quality of instruction is positively associated with the teacher’s engagement in experimentation and reflective practice. In addition, teachers with a stronger sense of self-efficacy are more likely to engage in professional learning activities (Thoonen et al., 2011). Importantly, more frequent collaboration during these learning activities is positively associated with more frequent experimentation and reflection. Also, according to the results, teachers who collaborate are more likely to internalize the program’s goals and participate in decision-making processes (Thoonen et al., 2011). As revealed in Rhodes et al.’s (2009) study previously discussed, involving teachers in decision-making processes leads to improved school outcomes. Thus, a professional development program that encourages teachers to exercise their autonomy through engagement in experimentation, collaboration, reflection, and decision-making, in turn, enhances educational outcomes (Thoonen et al., 2011).

Professional development, when implemented effectively, provides teachers with the knowledge and skill-sets needed to successfully implement innovative, student-centered instructional practices. In regards to the private school context, autonomous teachers who are empowered to partake in education decision-making processes are more likely to construct professional agency and adopt practices promoted by reform initiatives (Rhodes et al., 2012; Thoonen et al., 2011). In addition, teachers who collaborate with colleagues and experts in the educational field receive the support and guidance necessary to effectively implement student-centered instructional practices that foster the learners’ critical thinking development (Donaldson, 2013; Yasumoto et al., 2001).
Professional Development in Critical Thinking Instruction

Professional development programs serve the important function of supporting teachers’ learning and application of instructional strategies that foster students’ critical thinking development. Extensive research aims to identify professional development features that most effectively produce change in teachers’ pedagogical practice. In general, professional development that provides ongoing support, encourages teacher collaboration and reflection, and provides training in innovative instructional strategies tends to promote positive change in teachers’ practice (Desimone et al., 2002; Donaldson, 2013; Duzor, 2011; Garet et al., 2001; Yasumoto et al., 2001). In particular, a cognitive apprenticeship professional development framework that incorporates Collins et al.’s (1989) cognitive dimensions with a focus on the key elements of critical thinking instruction – authentic learning, dialogue, and mentoring – provides teachers with a pedagogical model for effectively cultivating their students’ critical thinking abilities (Abrami et al., 2015).

Professional development through authentic learning. In addition to supporting teachers’ professional growth, professional development that models a student-centered learning environment promotes teachers’ adoption of critical thinking instructional practices (Major & Palmer, 2006). In particular, professional development that educates teachers in a variety of authentic, student-centered strategies and provides ample time to practice and reflect on the learned strategies promotes the adoption and effective transfer of the instructional practices to the classroom context (Duzor, 2011).

For example, as demonstrated by Major and Palmer (2006), teachers who practice problem-based learning (PBL) in a professional development setting adopt and transfer
this authentic, critical thinking instructional strategy to the classroom setting (Major & Palmer, 2006). In their study, Major and Palmer (2006) investigated the effectiveness of the PBL professional development program, which engaged the faculty in authentic, problem-based tasks, in promoting a shift from teacher- to student-centered pedagogy among the faculty participants. The researchers implemented the three-year intervention at a private university in the southeastern United States as part of the school’s reform movement to improve students’ critical thinking and problem-solving abilities. The researchers used a basic qualitative design to assess the effect of the intervention on the pedagogical beliefs and content knowledge of the 47 faculty participants. Analyses of the data, which included responses from one-to-one semi-structured faculty interviews and faculty portfolios completed during the professional development initiative, revealed that the PBL-based intervention effectively shifted the participants’ pedagogical beliefs to be more in alignment with student-centered learning (Major & Palmer, 2006).

Similar to Major and Palmer’s (2006) study, Wheeler et al. (2005) investigated the effects of a PBL course on participating teachers’ identity and professional practice. Participants in the small, qualitative, case study design included six teachers enrolled in an Information and Communication Technology course at the University of Plymouth, United Kingdom. For the duration of the course, the teacher participants collaborated virtually, using an online, PBL platform, to solve ill-structured problems relating to the teaching profession. For example, the participants were provided with a hypothetical scenario in which teachers in the faculty room engaged in a debate over the use of computers in the classroom. The teacher participants in the course worked collaboratively using the online platform to analyze the problem and develop multiple solutions to
address it (Wheeler et al., 2005). Analyses of in-depth, qualitative data, collected via interviews with the study participants, revealed that the online, PBL environment was positively associated with improvements in the teachers’ professional practice and identity. Although the generalizability of the findings is limited due to the small sample size and qualitative nature of the study, Wheeler et al.’s (2005) study provides a viable professional development framework for enhancing teachers’ critical thinking instruction. By modeling the effective use of PBL, the researchers’ virtual professional development platform facilitated the adoption and application of an authentic, critical thinking strategy in the classroom context.

Professional development through dialogue. The literature on professional learning and growth consistently supports the use of faculty collaboration as a vehicle to promote teachers’ adoption of instructional practices promoted by reform initiatives (Chong & Kong, 2012; Lave & Wenger, 1991; Yasumoto et al., 2001). In regards to critical thinking, professional development that provides opportunities for teachers to engage in different types of dialogue improves not only their pedagogical content knowledge but also their ability to effectively transfer similar collaborative, student-centered strategies to the classroom context (Wheeler et al., 2005). In addition, in the independent school setting where a teacher’s autonomy is especially valued, reform efforts that empower teachers to engage in collaborative reflection and decision-making processes in turn increase teachers’ professional agency and adoption of reform-oriented strategies (Rhodes et al., 2009; Robinson, 2012; Robinson & Timperley, 2007).

Professional development interventions that encourage teachers to collaboratively reflect upon their practice promote the effective transfer of the reform-oriented strategies
to the classroom setting (Duzor, 2011). In order to understand the effect of collaboration and reflection on teachers’ motivation to transfer learned strategies to the classroom context, Duzor (2011) performed a qualitative study of a professional development course taught by instructors from a university science outreach program. Seventeen K-8 teachers participated in the professional development course which integrated constructivist and situated sociocultural learning approaches to help the teacher participants develop connections between the course content and their classroom context. The qualitative methodology included observing the participants during the course and collecting teacher artifacts, including journal entries, interviews, and videos of the professional development classes. According to analyses of the in-depth, qualitative data, the professional development framework, in which teachers enhanced their pedagogical knowledge within the context of a reflective learning community, motivated the teacher participants to consistently transfer the learned strategies to the classroom context (Duzor, 2011).

**Professional development through mentoring.** In combination with authentic learning and dialogue, mentoring by more knowledgeable peers enhances students’ critical thinking development (Abrami et al., 2015). Thus, teachers who participate in professional development opportunities that model the mentoring component of instruction, in combination with authentic learning strategies and dialogue, may enhance their pedagogical knowledge of effective critical thinking practices. In addition, teachers who receive ongoing support and feedback via one-on-one mentoring from peers or experts in the educational field more effectively implement learned strategies and improve their professional practice over time (Park, Kim, Park, Park, & Jeong, 2015).
In order to determine the effect of mentoring on teachers’ professional practice, Park et al. (2015) investigated the effectiveness of their practical on-site cooperation model (POCoM) in improving science instruction in secondary schools. Their study aimed to decrease the gap between educational theory in student-centered instructional practices and classroom application of these practices. In the POCoM model, a researcher attempts to produce gradual improvement in instruction by observing the teacher in the classroom setting, identifying growth areas on an observation protocol checklist, and collaborating with the teacher immediately following the class to discuss his progress. The bottom-up approach and cyclical application of this process is intended to promote gradual improvement in teaching from one class to the next. In the study, the researchers used a qualitative approach to observe and video record the science classes (24 total) of three teacher participants. According to the findings, the cyclical application of the POCoM protocol produced a 63% improvement rate among the participants. Thus, regular classroom observations and subsequent feedback provided by the researcher effectively promoted the teacher’s more frequent implementation of student-centered instructional practices.

**Intervention**

In spite of research supporting the use of student-centered practices to foster students’ critical thinking development (Abrami et al., 2015), the needs assessment study revealed that teacher-centered practices persist among science classrooms at a secondary, independent, Catholic school (ICS) (Macek, 2015). The science teachers’ inadequate adoption of student-centered learning approaches thus necessitated the implementation of a professional development intervention that would target and improve the teachers’
instructional practice at ICS. In order to produce the desired outcome – increased teacher adoption of critical thinking instructional practices – research-based treatments were strategically and sequentially delivered via professional development workshops and mentoring sessions provided to participating science teachers at ICS.

Over a period of six months, the researcher delivered a combination of theory-driven, professional development activities to the science teacher participants in order to increase their adoption of student-centered instructional practices that would ultimately improve the students’ critical thinking development. The purpose of including the science teachers as the primary research subjects was to promote change in the mediating variables – the teachers’ knowledge and pedagogical beliefs – which, in turn, would influence their level of adoption of student-centered learning approaches (Ertmer et al., 2012; Rogers, 2003; Smith, 2000). The teacher participants self-selected to one of two groups: a treatment group or a control group. The treatment group members collaboratively participated in four professional development workshops, facilitated by the researcher, to enhance their knowledge of critical thinking development and research-based, student-centered instructional strategies that cultivate critical thinking. Additionally, the treatment group members participated in four “mentoring” sessions in-between the professional development workshops to receive personalized observation feedback on their classroom practice and to engage in in-depth reflection on their professional growth.

According to the literature, the intervention framework would promote the teacher participants’ adoption of student-centered instructional practices that foster students’ critical thinking development (Desimone et al., 2002; Elder & Paul, 2008; Stewart &
Lagowski, 2003). Through the application of the cognitive apprenticeship model, participation in the professional development workshops, in combination with the mentoring sessions, was expected to enhance the professional growth of the participants in the area of critical thinking instruction. Ultimately, the increased adoption and implementation of the learned instructional practices would likely enhance students’ critical thinking development and thus their preparedness for academic endeavors that demand the application of higher-order cognitive abilities (Abrami et al., 2015; Holt et al., 2015).

**Key Components: Professional Development and Mentoring**

The treatment group members participated in four professional development workshops in addition to four mentoring sessions. The professional development workshops incorporated best practices that promoted the professional growth of educators and the effective transfer of the learned strategies to the classroom context. Because the workshops were sustained over a six-month time period and provided active learning opportunities for the teacher participants, they were expected to positively influence the participants’ learning outcomes (Garet et al., 2001). Furthermore, training in a variety of 21st century instructional strategies was included in the workshops to pique the teachers’ interest and motivate them to attempt the learned strategies in their classes (Desimone et al., 2002; Henderson, 2008). The mentoring component of the intervention provided opportunities for the treatment group participants to receive additional, personalized support to further enhance their professional growth (Henderson, 2008). By providing additional opportunities for learning and reflection through the interactive sharing of ideas and expertise, the mentoring sessions served to enhance the teacher’s pedagogical
content knowledge in critical thinking instruction and professional growth over time (Major & Palmer, 2006; Vacilotto & Cummings, 2007). Both the mentoring and professional development components of the intervention modeled cognitive apprenticeship theory by guiding the participants through the four dimensions of this pedagogical framework: content, method, sequence, and sociology (Collins et al., 1989; Stewart & Lagowski, 2003).

**Content dimension.** As learners proceed through the content dimension, they develop the requisite domain knowledge and acquire strategies for learning and performing the various tasks inherent to the given subject area (Stewart & Lagowski, 2003). In the professional development workshops, the researcher guided the participants (apprentices) through the content dimension by providing them with information on research-based, student-centered learning strategies that foster critical thinking development. In particular, the professional development workshops focused on problem-based learning (PBL) and inquiry-based learning, both student-centered approaches that cultivate students’ critical thinking skills as the students work collaboratively to construct their knowledge and solve complex, authentic problems (Marshall & Horton, 2011; Sungur & Tekkaya, 2006; Tiwari et al., 2006). The mentoring sessions provided the participants with additional opportunities to reflect on the learned instructional strategies.

**Method dimension.** During the method dimension, the learner experiences significant growth through modeling and coaching by an expert in the field, reflecting on his knowledge, and exploring novel strategies for independently solving problems in the field (Stewart & Lagowski, 2003). The professional development workshops incorporated the method dimension by providing opportunities for the participants to
observe videos of model lessons and discuss strategies for integrating novel pedagogical approaches into their classroom practice. Furthermore, the researcher scaffolded the participants’ learning by initially providing ample support structures and then “fading” the support so that the teachers could problem-solve and apply their new knowledge to their particular teaching context (Stewart & Lagowski, 2003; Wheeler et al., 2005).

Further modeling the method dimension, both the professional development workshops and the mentoring sessions provided opportunities for the treatment group members to engage in collaborative reflection on their professional practice and growth. Teacher reflection, an important component of effective professional development programs, facilitates the teachers’ ability to diagnose instructional problems, to establish goals and identify strategies for improvement, and to effectively transfer the strategies to the classroom context (Belvis et al., 2013; Duzor, 2011; Rhodes et al., 2009; Robinson, 2012). In particular, during the mentoring sessions, the treatment group members reflected on the RTOP (Sawada et al., 2002) feedback provided by the researcher’s observations of their classroom practice. Importantly, the participants explored strategies for increasing their RTOP score to a level (III or IV) that is in alignment with a student-centered, critical thinking learning environment (Holt et al., 2015).

In addition to being a source of reflection for teachers desiring to analyze and improve their practice, the ongoing and objective nature of the RTOP feedback was expected to further promote the teachers’ professional growth (Donaldson, 2013). When compared to the subjective feedback traditionally provided to teachers in private schools (Master, 2014), the objective observation feedback provided via the application of the RTOP instrument was more likely to produce positive change in the teachers’ practice.
(Donaldson, 2013). Finally, because observations of the teachers’ classroom practice were performed consistently on a continual feedback cycle, and the RTOP observation feedback was provided to the teachers immediately following the observed lessons, the teachers were more likely to adopt and implement the recommended strategies and improve their professional practice over time (Park et al., 2015).

**Sequence dimension.** Following the method dimension, the sequence dimension of the cognitive apprenticeship model involves the development of the learners’ skills and expertise through the performance of authentic tasks of increasing complexity and diversity (Stewart & Lagowski, 2003). To model the sequence dimension, the professional development workshops provided opportunities for the participants to practice PBL and inquiry-based learning approaches and to develop lessons that they would implement in their classes. For example, to practice the PBL approach, the treatment group participants were given an authentic, ill-structured problem to solve during one of the professional development workshops (Wheeler et al., 2005). They then worked collaboratively with their peers to construct their understanding of the problem and develop a viable solution. Because the teachers were given the opportunity to practice the learned instructional strategies during the professional development workshops, they were more likely to adopt and effectively implement these approaches in the classroom setting (Major & Palmer, 2006; Wheeler et al., 2005).

**Sociology dimension.** Finally, during the sociology dimension, the instructor guides learners towards the desired level of expertise by providing an authentic learning environment in which learners take on the role of expert, actively collaborating with one another and applying their acquired knowledge to solve complex problems and achieve
established goals (Stewart & Lagowski, 2003). As part of the sociology dimension, the participants had the opportunity to practice the learned critical thinking strategies within their authentic, classroom settings. In addition, the researcher used the RTOP instrument to observe and provide feedback to the participants on the effectiveness of their classroom implementation of the learned critical thinking instructional strategies. Further, the mentoring sessions provided ample time for the participants to analyze the RTOP feedback, collaboratively reflect on their use of the learned critical thinking instructional strategies, and brainstorm strategies for improving the effectiveness of their professional practice over time.

Ultimately, by modeling the cognitive apprenticeship framework, the professional development workshops and mentoring sessions guided the participants towards expertise in critical thinking instruction by providing them with learning opportunities that positively influenced their pedagogical belief systems, knowledge acquisition, and problem-solving abilities (Collins et al., 1989; Stewart & Lagowski, 2003). In addition, by establishing a collegial network, providing ample instructional resources, and building on the teacher’s expertise and strengths, the professional development workshops and mentoring sessions empowered and motivated the teachers to enhance their professional practice in critical thinking instruction (Desimone et al., 2002; Vacilotto & Cummings, 2007; Yasumoto et al., 2001). In turn, with the teachers’ increased adoption of the learned critical thinking strategies, their students may experience enhanced critical thinking development over time (Abrami et al., 2015). As a result, their students may be better prepared to succeed in coursework and careers that demand the application of critical
thinking and problem-solving abilities (Abrami et al., 2015; Garet et al., 2001; Holt et al., 2015).

Figure 3

A Cognitive Apprenticeship Model for Professional Development
Discussion and Conclusion

In the private, independent school sector, the persistence of teacher-centered instructional practices continues to hinder students’ development of critical thinking skills (Lubienski et al., 2008; Macek, 2015). In order to effectively cultivate students’ critical thinking, teachers must align their beliefs with student-centered pedagogy and implement innovative practices within a constructivist, learner-centered environment (Elder & Paul, 2008; Ertmer & Newby, 1993; Ertmer et al., 2012). A transition to student-centered pedagogy is particularly challenging in autonomous, independent school cultures (Bidwell & Dreeben, 2003). Therefore, the intervention sought to effectively accomplish this transition to student-centered pedagogy by addressing the unique challenges posed by the independent school culture.

A review of the literature provides key themes and theoretical frameworks that were incorporated into the intervention which targeted the instructional practice of teachers in a private, independent school. First, because the intervention modeled cognitive apprenticeship theory, it fostered the participants’ professional growth by guiding them through the cognitive dimensions of content, method, sequence, and sociology (Collins et al., 1989). As the teachers proceeded through the dimensions, the mentor (researcher) used approaches such as scaffolding, coaching, expert feedback, and observing to support the teachers in their growth. The teachers played an integral role in their own professional growth by actively reflecting on their practice and modeling the practice of experts in the field. Over time, guided by the cognitive apprenticeship professional development framework, the teacher participants became more
knowledgeable of critical thinking instructional practices and strategies for effectively implementing these practices in the classroom setting.

In addition to adhering to a cognitive apprenticeship approach to learning, the intervention modeled research-based approaches to critical thinking development. In particular, the incorporation into the intervention of authentic learning opportunities, dialogue with peers, and mentoring, all key components of critical thinking instruction (Abrami et al., 2015), provided the participants with the knowledge and skill-sets necessary to support their students’ cognitive development. In the professional development setting, the teachers were provided ample time to collectively discuss, reflect upon, and practice the promoted strategies within an authentic, classroom setting. Also, mentoring, a critical element of the intervention design, was provided to the teacher participants throughout the intervention to support their ongoing professional growth and application of the learned instructional strategies. By observing the teachers in the classroom setting and providing in-depth feedback on their instructional practice, the researcher supported the teachers’ professional growth in a cyclical process of observation, feedback, reflection, and application of recommended strategies. In turn, this level of personalized mentoring and support by the researcher was expected to be a key ingredient for fostering the teachers’ adoption of critical thinking instruction.

Furthermore, in order to encourage teacher-level change that would ultimately lead to gains in students’ critical thinking, the intervention strategically integrated the key components of critical thinking instruction with evidence-based professional development strategies. As such, the professional development intervention aligned with professional learning approaches advocated by researchers such as Desimone et al.
(2002) and Garet et al. (2001). For example, the intervention provided training in specific critical thinking strategies, promoted collaboration and reflection, maintained coherence, and built on teachers’ expertise to encourage their adoption of student-centered instructional practices.

Finally, the intervention was designed to foster the professional growth of educators within the culture of the independent, private school setting. To that end, in order to be effectively implemented and to promote the desired outcomes, the intervention design took into account the culture of autonomy typically embraced by faculty members in the independent school context. In turn, the professional development intervention leveraged, instead of suppressed, the teachers’ autonomy in an effort to more effectively garner support and promote the teachers’ adoption of the recommended practices. For example, because the intervention encouraged the teachers to learn from each other, collectively reflect on their pedagogy, and establish professional goals, it encouraged the teachers to grow in their practice while maintaining their autonomy. Furthermore, because the teachers were empowered to partake in instructional decision-making processes and received ongoing support as they worked to achieve their goals, they were more motivated to exercise their professional agency and develop as educators. Overall, because the professional development program modeled cognitive apprenticeship approaches and evidence-based critical thinking instruction, provided teachers with ongoing support and feedback, and leveraged the teachers’ autonomy in decision-making processes, the intervention was expected to achieve the desired outcome: increased teacher adoption of critical thinking instructional practices.
Project Objectives

1. To implement a professional development intervention within the science department of a private, independent school to promote the teacher participants’ adoption of evidence-based, student-centered practices designed to enhance students’ critical thinking development.

2. To evaluate the intervention’s fidelity of implementation.

3. To evaluate the intervention’s effectiveness in producing positive changes in the desired short-term outcomes: increased levels of pedagogical beliefs aligned with student-centered practices and knowledge of critical thinking instruction.

4. To evaluate the intervention’s effectiveness in producing positive change in the desired medium-term outcome: teachers’ effective adoption of critical thinking instructional practices.

Research Questions

1. To what extent does the intervention produce positive change in the teachers’ knowledge of instructional practices that foster students’ critical thinking?

2. To what extent does the intervention produce positive change in the teachers’ pedagogical beliefs about critical thinking instructional practices?

3. How effective is the intervention in increasing the teachers’ adoption of critical thinking instructional practices?
Chapter 4

Intervention

The following sections provide a detailed overview of the intervention implemented within the Science Department at ICS. In particular, the sections outline the resources required for the implementation of the professional development (PD) intervention, the data collection instruments, the intervention methodology, the process and outcome evaluation plans, and the data analyses.

Resources

In order to ensure the effective implementation of the PD intervention, several resources were required. First, the intervention required the support and participation of several human resources within the school. In particular, the participation of middle and high school science teachers was needed for the successful implementation of the intervention. The 15 Science Department members were given the opportunity to participate in the study in either the treatment group or the control group. The intervention required both the treatment and control group members to respond to pre- and post-intervention survey questions and to be formally observed in their classroom environment pre- and post-intervention. The treatment group members also participated in four 90-minute PD workshops and four 30-minute mentoring sessions, performed peer observations, and implemented in their classes critical thinking assignments to develop their knowledge and ultimately increase their adoption of critical thinking instructional practices.

In addition to the participation of the science teachers, various technology resources were needed to ensure the intervention’s successful implementation. In
particular, the teachers needed access to the following: laptop computer, Epson projector, and SurveyMonkey.com. As part of the school’s one-to-one laptop program, each teacher was provided with a laptop computer. Also, at ICS, every classroom and meeting space is equipped with an Epson projector. The projectors, in conjunction with laptop computers, were used in the PD workshops to project PowerPoint presentations that informed the participants about critical thinking components and practices, and to project videos of lessons that incorporate critical thinking instructional approaches. Finally, SurveyMonkey.com was used for the electronic administration of pre- and post-intervention surveys to the teacher participants.

**Participant Selection**

Prior to the intervention, the science teachers who volunteered to participate in the study self-selected to either the treatment group or the control group. The researcher expected that permitting the teachers to select the group that most interested them would increase the likelihood of their participation. During the selection process, ten science teachers opted to participate in the treatment group and five opted to participate in the control group. While the treatment and control groups were not of equal size, the control group provided a useful sample against which to compare the treatment group’s data.

Because participant self-selection poses a threat to internal validity (Shadish et al., 2002), steps were taken to increase the plausibility that the observed effects were caused by the intervention treatment. First, by limiting study participation to secondary science teachers, the study controlled for subject area (science) and teaching level (secondary) and thus decreased validity threats posed by confounding variables (Shadish et al., 2002). In addition, the effects of the treatment on the mediating, moderating, and outcome
variables were assessed using a pretest-posttest control group design (Shadish et al., 2002). This particular study design increased the likelihood that the observed effects were attributed to the treatment as opposed to random change that might have occurred in the absence of the intervention. Furthermore, the researcher used the pre-intervention teacher survey to assess each group’s demographic data at pretest. The pre-intervention data, to be discussed further in the study findings, revealed similar demographic trends between the treatment group and control group in terms of the participants’ subject areas and years of teaching. Therefore, while the uneven sample sizes increased threats to internal validity, the study design and the groups’ similar demographics helped to mitigate any validity threats and increased the plausibility that the observed effects could be attributed to the treatment (Shadish et al., 2002).

**Instruments**

Specific instruments were used throughout the study to determine the participants’ professional growth over time and the extent to which the observed effects could be attributed to the specific intervention treatments.

**The Reformed Teaching Observation Protocol.** The researcher used the Reformed Teaching Observation Protocol (RTOP), a quantitative classroom observation instrument, as the primary indicator of the participants’ level of adoption of critical thinking instructional practices. The RTOP is a valid and reliable instrument developed by the Evaluation Facilitation Group (EFG) of the Arizona Collaborative for Excellence in Preparation of Teachers (ACEPT) to measure “reformed” teaching among elementary and secondary mathematics and science teachers (Piburn, Sawada, & ACEPT, 2000, p. 1). The researchers developed their definition of “reformed teaching” based on extensive
research in mathematics and science education and on recent national standards (Piburn et al., 2000). Constructivism, a learning theory based largely on the works of Piaget and Vygotsky (Isikoglu et al., 2009), provides the theoretical framework for ACEPT’s definition of “reformed teaching” (Piburn et al., 2000). In addition, ACEPT’s definition of “reformed teaching” incorporates science education standards recommended by organizations such as the American Association for the Advancement of Science (AAAS, 1989) and the National Research Council of the National Academy of Sciences (NRC, 1996; NRC, 2000).

According to AAAS (1989), science educators need to prepare students with the inquiry skills inherent to scientific fields of study. According to the National Research Council, science teaching should “start with questions about nature; engage students actively; concentrate on the collection and use of evidence; not separate knowing from finding out” (NRC, 1996, p. 30). In addition, ACEPT reform, in accordance with recent reform documents (AAAS, 1989; NRC, 1996; NRC, 2000), defines good science teaching as that which: challenges students to apply their prior knowledge to develop understanding of concepts; adapts to the interests, skills, and backgrounds of the learners; allows students to formulate conclusions through the active manipulation of concrete objects and data; encourages student collaboration and engagement to promote communication, student responsibility, and knowledge construction; and, provides opportunities for students to reflect on their work.

The RTOP instrument served as an effective measure of research-based, student-centered science instruction due to its alignment with current science reform initiatives and its application of constructivist learning theories to its evaluation protocol (Piburn et
al., 2000). Of particular interest to this study, as discussed by Holt et al. (2015), RTOP provides an effective measure of student-centered instructional practices that foster critical thinking development. The researcher therefore used the RTOP instrument to rate the participants on the effectiveness with which they implemented in their classes research-based, student-centered instructional strategies that promote critical thinking development (Holt et al., 2015). A comparison of the RTOP ratings between the treatment and control groups over time indicated the extent to which the treatment influenced change in teachers’ instructional practice.

**RTOP design.** The RTOP consists of 25 Likert-scale questions divided into three subscales, with each subscale designed to measure a component of ACEPT’s model of reformed teaching (Piburn et al., 2000). The first subscale measures the teacher’s “lesson design and implementation” and consists of five questions (Piburn et al., 2000, p. 29). The second subscale measures content knowledge by operationalizing this construct into two subsets, “propositional knowledge” and “procedural knowledge,” each consisting of five questions (Piburn et al., 2000, p. 29). The third subscale measures classroom culture by operationalizing this construct into two subsets, “communicative interactions” and “student/teacher relationships,” each consisting of five questions (Piburn et al., 2000, p. 31). Each subscale provides five scaled responses from 0 (“Never Occurred”) to 4 (“Very Descriptive”) from which the observer selects the rating that best characterizes the teacher’s performance on each question. Therefore, a total RTOP score may range from 0, indicating that reform-oriented teaching “never occurred,” to 100, indicating that the lesson characteristics and teacher’s pedagogy are “very descriptive” of reformed teaching throughout the lesson (Piburn et al., 2000).
To use the overall RTOP score to determine the effect of the teachers’ instructional practice on the students’ application of critical thinking skills, the RTOP score can be divided into five levels: level I (scores of 15 to 30), or “strictly teacher-centered lecture;” level II (scores of 31 to 45), or “teacher-centered lecture shifting toward learner-centered classroom with student involvement;” level III (scores of 46 to 60), or “learner-centered classroom;” level IV (scores of 61 to 75), or “learner-centered with critique;” and, level V (scores of 76 to 100), or “complete learner-centeredness involves critique, open-ended inquiry, hypotheses, and critical reflection” (Holt et al., 2015). Because a level III RTOP score (46 to 60 points) promotes increased critical thinking when compared to a level II RTOP score (Holt et al., 2015), a total RTOP score of 46 represented the minimum score to be attained by the treatment group members after their participation in the intervention. RTOP scores within the level III range (46 to 60 points) indicated the effective implementation of instructional practices that foster critical thinking development, with higher scores providing increased opportunities for critical thinking gains than lower scores (Holt et al., 2015). With continued professional development, support, and practice, the participants may increase their total RTOP scores to the level IV or V categories, demonstrating increased and enhanced use of student-centered instructional strategies that cultivate critical thinking (Holt et al., 2015).

**Subscale I: Lesson Design and Implementation.** The first RTOP subscale measured the teacher’s “lesson design and implementation” (Piburn et al., 2000, p. 29). To do so, the five Likert-scale questions rated the lesson and the teacher’s use of instructional strategies on the level to which they: “respected students’ prior knowledge and preconceptions inherent therein,” “engaged students as members of a learning
community,” placed “student exploration” before “formal presentation,” “encouraged students to seek and value alternative modes of investigation or of problem solving,” and allowed “the focus and direction of the lesson” to be “determined by ideas originating with students” (Piburn et al., 2000, p. 29). A rating of “0” indicated that the identified instructional strategy never was observed occurring, while a rating of “4” indicated that the identified instructional strategy was “very descriptive” of that strategy being regularly observed throughout the lesson (Piburn et al., 2000, p. 29).

**Subscale II: Content.** The second RTOP subscale measured two aspects of the teacher’s content knowledge: “propositional knowledge” and “procedural knowledge” (Piburn et al., 2000, p. 29). In the “propositional knowledge” subscale, the five Likert-scale questions rated the quality of the lesson’s content by measuring the level to which: the lesson “involved fundamental concepts of the subject” and “promoted strongly coherent conceptual understanding;” “the teacher had a solid grasp of the subject matter content inherent in the lesson;” “elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so,” and, “connections with other content disciplines and/or real world phenomena were explored and valued” (Piburn et al., 2000, p. 29). A rating of “0” signified that the identified indicator of the lesson’s content quality “never occurred” in the observation, while a rating of “4” signified that the identified indicator of quality content was “very descriptive” of that indicator being regularly observed throughout the lesson (Piburn et al., 2000, p. 29).

In the “procedural knowledge” subscale, the five Likert-scale questions measured the teacher’s use of inquiry processes, an important component of ACEPT reform (Piburn et al., 2000). To do so, the questions rated the level to which: “students used a variety of
means (i.e., models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena,” “students made predictions, estimations and/or hypotheses and devised means for testing them,” “students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures,” “students were reflective about their learning,” and “intellectual rigor, constructive criticism, and the challenging of ideas were valued” (Piburn et al., 2000, p. 29). A rating of “0” indicated that the identified component of the inquiry process “never occurred” in the observation, while a rating of “4” indicated that the identified inquiry component was “very descriptive” of the inquiry process being regularly observed throughout the lesson (Piburn et al., 2000, p. 29).

**Subscale III: Classroom Culture.** The third RTOP subscale measured two aspects of the classroom environment and culture: the “communicative interactions” and the “student/teacher relationships” (Piburn et al., 2000, p. 31). In the first subscale, the five Likert-scale questions measured the communicative interactions within the class by rating the level to which: “students were involved in the communication of their ideas to others using a variety of means and media,” “the teacher’s questions triggered divergent modes of thinking,” “there was a high proportion of student talk and a significant amount of it occurred between and among students,” “student questions and comments often determined the focus and direction of classroom discourse,” and, “there was a climate of respect for what others had to say” (Piburn et al., 2000, p. 31). A rating of “0” signified that the identified indicator of communicative interactions “never occurred” in the observation, while a rating of “4” signified that the type of communication identified was
“very descriptive” of the interactions being regularly observed throughout the lesson (Piburn et al., 2000, p. 31).

In the second subscale, the five Likert-scale questions measured the student/teacher relationships. To do so, the questions rated the level to which: “active participation of students was encouraged and valued,” “students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence,” “in general the teacher was patient with students,” “the teacher acted as a resource person, working to support and enhance student investigations,” and, “the metaphor ‘teacher as listener’ was very characteristic of this classroom” (Piburn et al., 2000, p. 31). A rating of “0” signified that the identified indicator of student/teacher relationships “never occurred” in the observation, while a rating of “4” signified that the identified characteristic was “very descriptive” of the teacher/student relationships being regularly observed throughout the lesson (Piburn et al., 2000, p. 31).

**RTOP reliability and validity.** The reliability of the RTOP instrument for use in measuring reformed teaching was confirmed via the analysis of two separate data sets collected during the ACEPT evaluation process. As part of this evaluation process, two members of the Evaluation Facilitation Group (EFG) used RTOP to separately observe and rate 16 video-recorded lessons (for a total of 32 observations). The high inter-rater reliability, estimated to be 0.954, was determined by comparing the two sets of observations via a best-fit linear regression (Piburn et al., 2000). In addition, best-fit linear regressions were performed to estimate the reliability of each of the five RTOP subscales. The reliability estimates (or R², which indicates the proportion of variance accounted for by the line of best fit) ranged from 0.670 (Subscale 2: Content –
Propositional Knowledge) to 0.946 (Subscale 3: Content – Procedural Knowledge).

While they are not as high as the RTOP’s total reliability score ($R^2 = 0.954$), Piburn et al. (2000) assert that the reliability estimates for the RTOP subscales are considered to be relatively high for this type of observation instrument.

In addition to the RTOP’s reliability, extensive evidence confirmed the validity of the instrument. Among the different types of validity, construct validity, or “the theoretical integrity of an instrument” (p. 12), is of critical importance for an observation instrument (Piburn et al., 2000). To have construct validity, the correlations between the instrument’s constructs must reflect theoretical relationships identified in the literature. In particular, the theoretical constructs that form the foundation of ACEPT reform include inquiry-based and standards-based teaching. Therefore, to estimate the instrument’s construct validity, a correlational analysis was performed on each RTOP subscale to predict the total score, with high $R^2$ values indicating high construct validity. In particular, this analysis revealed the extent to which inquiry-based instruction influences the relationship between the standards-based subscales and the total score. Because the $R^2$ value for each subscale (ranging from 0.769 to 0.971) approaches the reliability estimates, the evidence confirms the construct validity of the RTOP instrument (Piburn et al., 2000).

**Survey.** In addition to RTOP, a survey (Appendix C) was administered (via SurveyMonkey.com) to both the treatment and control group members pre- and post-intervention in order to measure the magnitude of change in the mediating variables (teachers’ knowledge of critical thinking practices and pedagogical beliefs about student-centered instruction), the respondents’ perceived level of adoption of critical thinking
instructional practices, and the participants’ level of engagement in the different intervention components. In part one of the survey, three questions with multiple-choice response options asked the respondents to provide demographic information, including the science subject area taught, total years of teaching, and total years of teaching at ICS. In part two of the survey, 22 Likert-scale questions were developed using existing instruments, including the RTOP and surveys developed by Stapleton (2011) and Isikoglu et al. (2009), to measure the respondents’ knowledge and beliefs about various aspects of critical thinking instruction. For each Likert-scale question, the respondent selected an option from the 5-point scaled responses, with 1 representing strongly disagree and 5 representing strongly agree. In addition, one qualitative, open-ended question was used to find the respondents’ definition of critical thinking.

In part two of the survey, the questions (1-8) adapted from Stapleton’s (2011) study of secondary school teachers’ attitudes towards critical thinking, measured the teachers’ perceptions of various aspects of critical thinking instruction. In particular, the questions measured the respondents’ beliefs about: the meaning of critical thinking, the role of critical thinking in their science subject area, and their need for training in critical thinking instructional approaches. The survey questions (9-14) adapted from Isikoglu et al.’s (2009) study of teachers’ instructional beliefs about student-centered education, measured the extent to which the teachers’ pedagogical beliefs and instructional practices align with student-centered approaches that cultivate critical thinking. The survey questions (15-22) adapted from the RTOP subscales measured the respondents’ knowledge of instructional practices that foster critical thinking development. Question 23, an open-ended question adapted from Stapleton’s (2011) study of teachers’ attitudes
towards critical thinking, required a written response in an effort to more accurately assess the teachers’ existing knowledge of the meaning of critical thinking.

In part three of the survey, the Likert-style questions (24-37) asked the participants to rate their level of involvement in specific components of the intervention. The researcher designed these questions to determine the extent to which the participants engaged in the theory-based intervention components, including: the professional development activities, mentoring sessions, peer collaboration, peer observations, reflection on RTOP feedback, and critical thinking assignments. The participants’ responses provided an indication of the degree to which the observed outcomes can be attributed to the participants’ perceptions of their level of engagement in specific intervention components.

**Critical thinking assignments.** During the intervention, two instructional tools, both developed by the Foundation for Critical Thinking (2015), were provided to the treatment group participants to support their adoption of instructional practices that foster students’ critical thinking development (Appendix C). First, the “Criteria for Critical Thinking Assignments” (Foundation for Critical Thinking, 2015) provided the participants with specific guidelines to support their development of assignments that cultivate their students’ critical thinking. This instructional tool guided the participants in developing assignments that included the necessary criteria for promoting critical thinking development. In order to meet the standards established by the Foundation for Critical Thinking (2015), the assignment would need to meet all four criteria outlined in the tool. To that end, the teacher was asked to provide, via a written response, evidence that the assignment fulfilled each criterion. The tool also provided a check-list of the
cognitive skills that are needed to develop critical thinking so that teachers could gauge the assignment’s overall effectiveness. For the second criterion, the teacher was asked to identify from this check-list the cognitive skills that students must apply to complete the assignment.

Second, the treatment group participants were provided with the “Critical Thinking Grid” (Foundation for Critical Thinking, 2015), a useful rubric for assessing their students’ performance on critical thinking assignments and tasks (Appendix C). Using the rubric, the teacher rated, using a scale from 1 (unsatisfactory) to 4 (exemplary), the students’ application of critical thinking to complete the following assignment components: identify the purpose, define the problem, examine and evaluate different points of view, gather and interpret credible and relevant information, identify and accurately explain key concepts, identify and make valid assumptions, formulate logical inferences and conclusions based on evidence, and identify key implications of the findings (Foundation for Critical Thinking, 2015). The participants were asked to use both the “Criteria for Critical Thinking Assignments” and the “Critical Thinking Grid” at three time points during the intervention to develop and evaluate critical thinking assignments for their classes.

When used appropriately to design, implement, and evaluate critical thinking assignments, the critical thinking instructional tools should produce high consequential validity as designated by the Foundation for Critical Thinking (2015). That is, when teachers design assignments that meet all of the criteria stated on the “Criteria for Critical Thinking Assignments” tool and effectively implement instructional tasks that cultivate the students’ critical thinking, the students should be expected to perform well on the
assignments as measured by the criteria outlined in the “Critical Thinking Grid” (Foundation for Critical Thinking, 2015). Therefore, the teachers’ effective implementation of critical thinking tasks could be assessed by their students’ performance on these tasks as indicated by the Critical Thinking Grid scores. The students’ performance on the critical thinking tasks could be determined by calculating the overall score (1-4) from the “Critical Thinking Grid,” where: “4 = Thinking is exemplary, skilled, marked by excellence in clarity, accuracy, precision, relevance, depth, breadth, logicality, and fairness; 3 = Thinking is competent, effective, accurate and clear, but lacks the exemplary depth, precision, and insight of a 4; 2 = Thinking is inconsistent, ineffective; shows a lack of consistent competence: is often unclear, imprecise, inaccurate, and superficial; 1 = Thinking is unskilled and insufficient, marked by imprecision, lack of clarity, superficiality, illogicality, and inaccuracy, and unfairness” (Foundation for Critical Thinking, 2015).

**Interview.** Following the PD and mentoring components of the intervention, the researcher conducted semi-structured interviews with the treatment group members to determine their perceptions of the intervention’s influence on their practice. In particular, the interview questions, generated by the researcher, served to collect the participants’ perceptions of: how the intervention compared to other professional development programs in which they have participated, the intervention components that most and least influenced their instructional practice, the extent to which they changed their practice as a result of participating in the intervention, and the intervention components that should be targeted for improvement. The participants’ responses to the interview questions addressed the research questions as they provided insight into their knowledge
of critical thinking instruction, beliefs about student-centered pedagogy, and the extent to which the intervention treatments promoted their adoption of critical thinking instructional practices. Thus, the interview questions served to reveal the relative effectiveness of the different components of the treatment in producing change in the participants’ pedagogical beliefs, knowledge, and practice in the area of critical thinking instruction.

**Course evaluations.** Immediately before and then again after the completion of the intervention, the “Course Evaluation Form,” developed by the Foundation for Critical Thinking (2007), was administered to the students in the classes of participants in the treatment and control groups (Appendix C). The “Course Evaluation Form,” a questionnaire consisting of 20 Likert-scale questions, required the students to rate the teacher’s use of critical thinking strategies on a scale of 1 (*low score*) to 5 (*high score*). Therefore, the purpose of the “Course Evaluation Form” was to measure, pre- and post-intervention, the student perceptions regarding the extent to which the teacher implemented instruction that fostered critical thinking development (Foundation for Critical Thinking, 2007).

**Methodology**

Over a period of five months, the researcher delivered a combination of theory-driven professional development activities (independent variables) to the teacher participants in order to increase their adoption of student-centered instructional practices (dependent variable; medium-term outcome) that should ultimately improve the students’ critical thinking development (dependent variable; long-term outcome). The professional development program was designed using a cognitive apprenticeship framework (Stewart...
and recent research in professional learning as it relates to critical thinking pedagogy (Desimone et al., 2002; Elder, 2005). The purpose of including the science teachers as the primary research subjects was to promote change in the mediating variables – the teachers’ pedagogical beliefs and knowledge of critical thinking practices – which, in turn, may influence their level of adoption of student-centered, critical thinking learning approaches. The teacher participants self-selected to one of two groups: a treatment group or a control group. The treatment group members participated in four 90-minute professional development (PD) workshops, facilitated by the researcher, to deeply explore critical thinking components and instructional practices that foster critical thinking development. In addition, the treatment group members participated in four 30-minute mentoring sessions to receive personalized and in-depth observation feedback from the researcher and to reflect on their professional growth. Maintaining high fidelity of implementation of these study components was of the utmost importance for ensuring the intervention’s overall effectiveness (Saunders, Evans, & Joshi, 2005). Therefore, throughout the research study, the researcher used various instruments and indicators to measure the intervention’s fidelity of implementation (further discussed under Data Collection).

**Observation protocol.** Both pre- and post-intervention, the researcher performed one observation of each treatment and control group participant’s classroom practice. In addition, at two separate time points during the intervention, each treatment group participant was observed by a peer (also in the treatment group), meaning that each treatment group participant also had the opportunity to observe a peer from the PD program. The RTOP instrument served as the tool for rating the teachers’ classroom
performance and for providing feedback to the treatment group participants on pedagogical areas to target for improvement. Following each observation, the researcher met with the treatment group participants individually (after the first formal observation) or in groups of three (after each peer observation). Each group of three consisted of the researcher and the two peers who observed each other. During these mentoring sessions, the participants worked collaboratively with the researcher to reflect on their RTOP feedback and to brainstorm strategies for improving their critical thinking instructional practice. During each of the second, third, and fourth mentoring sessions, the researcher met jointly with each pair of participants assigned to one another for peer observations so that the participants could share with one another their RTOP feedback and suggestions for improvement. During these small group mentoring sessions, the researcher listened to the peer feedback, provided the participants with additional feedback using the RTOP criteria and critical thinking research, and suggested strategies that the participants may adopt in order to improve their application of the learned critical thinking instructional practices. The control group members were only observed pre- and post-intervention and were not provided with the RTOP criteria or feedback.

**Researcher observation #1.** The researcher performed the first observation before the start of the intervention. The researcher formally observed each treatment and control group participant in the classroom setting to determine the baseline RTOP score to which the post-intervention RTOP score would be compared. While all of the participants were informed of the scheduled time for the pre-intervention observation, none of the participants was provided the RTOP criteria prior to this first observation. The treatment group participants did, however, receive the researcher’s RTOP feedback immediately
following the lesson during the first round of mentoring sessions. During these mentoring sessions (which took place before PD workshop one), the researcher met individually with each treatment group participant to discuss and reflect on the RTOP feedback and to collaboratively brainstorm strategies for improvement. The researcher did not meet with nor provide the RTOP feedback to any of the control group participants.

**Researcher observation #2.** The researcher performed the second observation of each treatment and control group participant within one month following the completion of the intervention. This post-intervention observation, which was also scheduled with each treatment and control group participant, served to provide an indication of the professional growth experienced by the treatment group members as a result of participating in the intervention. The researcher provided the RTOP feedback to the treatment group participants following the observation. The control group participants were not provided with the RTOP feedback.

**Peer observation #1.** Additionally, on two separate occasions, each treatment group participant was observed by a peer from the treatment group. The first cycle of peer observations was performed in-between the first and second PD workshops. Prior to this observation, each treatment group participant was asked to complete a lesson template (Appendix C) that would inform the peer of the lesson’s objectives, design, and activities that support critical thinking development. The lesson template also included a checklist of cognitive skills (Foundation for Critical Thinking, 2015) to be fostered in the lesson. During the observation, the peer used the RTOP instrument to rate the effectiveness of the participant’s classroom practice and to provide the participant with targeted observation feedback. Prior to performing the observations, the treatment group
participants were encouraged by the researcher to be rigorous and honest in rating their peers’ classroom performance; as the researcher explained to the peer evaluators, few evaluations receive ratings of all “4s” because there is always room for professional growth and improvement. The participants also used the RTOP instrument immediately following the lesson to self-assess their own performance and then compared their personal evaluation to the peer’s evaluation of the lesson.

Following this first cycle of peer observations, the researcher held mentoring sessions in groups of three, such that each mentoring session consisted of the following individuals: the researcher, the participant who performed the lesson, and the peer who evaluated the lesson. This round of mentoring sessions provided an opportunity for the participants to discuss and reflect on their RTOP feedback with their peer evaluator. The researcher served to facilitate these sessions, allowing the participant and peer evaluator to use their developing expertise to collaboratively brainstorm strategies for improving the participant’s critical thinking instructional practice. The researcher also provided the participants with additional support by suggesting strategies for applying and improving the effectiveness of the learned critical thinking approaches in their classroom contexts.

Peer observation #2. The second peer observation, completed by the same peer from the treatment group, was performed in-between the third and fourth PD workshops. The same protocol was followed as discussed above for the first peer observation. Following this second cycle of peer observations, the researcher held mentoring sessions in groups of three, such that each mentoring session consisted of the following individuals: the researcher, the participant who performed the lesson, and the peer who evaluated the lesson. This round of mentoring sessions provided an opportunity for the
participants to discuss and reflect on their RTOP feedback with their peer evaluator. The researcher served to facilitate these sessions, allowing the participants and peer evaluators to use their developing expertise to collaboratively brainstorm strategies for improving the participant’s critical thinking instructional practice. The researcher also provided the participants with additional support by suggesting strategies for applying and improving the effectiveness of the learned critical thinking approaches in their classroom contexts.

The intervention’s critical elements expected to produce change included: (1) activities that increased the participants’ knowledge of critical thinking as a higher-order cognitive ability; (2) activities that increased the participants’ knowledge of instructional strategies (e.g., problem-based and inquiry-based learning) that foster students’ critical thinking development; (3) the classroom observations and the participants’ reflection on their RTOP feedback; (4) mentoring provided by the researcher to foster growth in the participants’ professional practice; and, (5) the participants’ collaborative reflection on their instructional practice and areas for professional growth. Because the research recommends participation in a minimum of four consecutive professional development sessions led by a critical thinking expert to produce change in the participants’ instructional practice (Paul & Elder, 2002), and reflection on instructional practice and observation feedback to increase the adoption of promoted practices (Donaldson, 2013; Duzor, 2011), the treatment’s dosage, timeframe, and mode of delivery were expected to produce the desired outcomes, in particular the increased teacher adoption of critical thinking practices.

Overview of PD workshops. Prior to the first PD workshop, each of the treatment group participants was provided with “The Miniature Guide to Critical
Thinking Concepts and Tools” by Paul and Elder (2009). This pamphlet provided the treatment group members with a clear and concise overview of critical thinking concepts and strategies and served as the primary resource to support the teachers’ learning during the PD workshops. In addition, the participants were provided with the article “Never Say Anything a Kid Can Say!” (Reinhart, 2000) and reflection questions on the article (Appendix C). They were asked to read the article and write written responses to the reflection questions, prepared by the researcher, prior to the first PD workshop. During the PD workshops, the researcher served as a mentor and coach to the treatment group participants, providing expertise in critical thinking instruction, facilitating in-depth discussions on the teachers’ instructional practice, and supporting the teachers’ transition to student-centered instructional practices that foster critical thinking development. Modeling a student-centered learning environment, the researcher guided the participants’ learning as they worked collaboratively to construct their understanding of critical thinking concepts, apply their knowledge to their instructional practice, and reflect on their professional growth.

**Professional development workshop #1.** The primary objectives of the first PD workshop were as follows: (1) to reflect on current research-informed instructional practices that foster critical thinking development; (2) to use research to inform the participants of the need for instruction that more effectively targets students’ critical thinking development; (3) to use “The Miniature Guide to Critical Thinking Concepts and Tools” (Paul & Elder, 2009) to provide an overview of critical thinking and the elements of thought; (4) to discuss a protocol for creating and assessing critical thinking assignments (Foundation for Critical Thinking, 2015); and, (5) to develop a critical
thinking assignment to be implemented in the participants’ classes. During the PD workshop, the participants were provided with an information packet consisting of the following two instructional tools: the “Criteria for Critical Thinking Assignments” and the “Critical Thinking Grid,” both developed by the Foundation for Critical Thinking (2015). The participants would use these tools to facilitate their development of a critical thinking assignment, which they were asked to assign to their students and evaluate before the second PD workshop.

The following provides the agenda for the PD workshop one activities implemented in an effort to meet each of the aforementioned objectives:

I. 15 minutes: The researcher began the workshop by asking the participants to collaboratively discuss their responses to the reflection questions that accompanied the article, “Never Say Anything a Kid Can Say!” (Reinhart, 2000). As they discussed their responses, one participant recorded on two separate, large pieces of chart paper: (1) the group’s definition of critical thinking, and (2) strategies that cultivate critical thinking development.

II. 20 minutes: The researcher distributed a packet that outlined the information to be learned in the workshops. The researcher used a PowerPoint presentation to define critical thinking, to discuss the importance of critical thinking in the secondary science classroom, and to provide an overview of the elements of thought and the universal intellectual standards (Paul & Elder, 2009).

III. 25 minutes: The researcher directed the participants to locate in the information packet the two Foundation for Critical Thinking (2015)
instructional tools: “Criteria for Critical Thinking Assignments” and “Critical Thinking Grid”. The researcher showed a 3-minute video, “Tiny House: A Community Project,” at https://www.teachingchannel.org/videos/tiny-house-collaborative-project-hth to provide an example of a critical thinking assignment. As the participants watched the video, they recorded responses to the following questions provided in a video template (Appendix C):

a. In the video, what component(s) of the “tiny house” assignment should the teacher evaluate using the critical thinking grid?

b. What elements of thought are incorporated into the “tiny house” assignment?

After the participants watched the video, they used the “tiny house” assignment presented in the video to collaboratively respond to the prompts on the “Criteria for Critical Thinking” (Foundation for Critical Thinking, 2015) template.

The researcher informed the participants of their first homework assignment: to use the critical thinking instructional tools to develop, implement, and evaluate a critical thinking assignment in their classes prior to PD workshop two.

IV. 25 minutes: The participants worked collaboratively to brainstorm ideas for assignments for their students that are aligned with curricular goals and that meet the criteria outlined in the Foundation for Critical Thinking (2015) instructional tools. After recording their ideas for possible critical
thinking assignments, each participant selected one assignment to be implemented in his class and used it to complete the “Criteria for Critical Thinking Assignments” template (Foundation for Critical Thinking, 2015).

V. 5 minutes: The researcher explained the protocol for conducting the peer observations. The researcher stressed the importance of providing rigorous and honest ratings of the teacher’s performance. The researcher assigned each participant to a peer (another treatment group participant) for the first peer observation, to be conducted within the next two weeks.

Professional development workshop #2. The primary objectives of the second PD workshop were as follows: (1) to review concepts learned in the first PD workshop, namely Paul and Elder’s elements of thought, the universal intellectual standards, and the criteria for critical thinking assignments; (2) to collaboratively discuss and reflect on the peer observation experience and areas for professional growth; (3) to provide an overview of the components of critical thinking instruction and to introduce inquiry-based learning as a pedagogical approach that cultivates critical thinking; and, (4) to work collaboratively to design lessons that incorporate inquiry-based learning, the universal intellectual standards, and the elements of thought (Paul & Elder, 2009) to promote critical thinking development.

The following provides the agenda for the PD workshop two activities implemented in an effort to meet each of the aforementioned objectives:

I. 20 minutes: The researcher used a PowerPoint presentation to review the concepts learned in the first PD workshop, namely the elements of thought
and the universal intellectual standards (Paul & Elder, 2009). The researcher then provided an overview of the components of lessons that foster critical thinking development. The researcher introduced inquiry-based learning as an example of an effective strategy for cultivating critical thinking.

II. 30 minutes: The participants viewed three short videos from the TeachingChannel.org to learn how to effectively implement inquiry-based learning approaches: “Carbon Cycling: Create Your Own Biology Lab,” “Introduction to Project-Based Learning Process,” and “Five Keys to Rigorous Project-Based Learning”. During each video, on a worksheet (Appendix C) developed by the researcher and provided in the information packet, the participants identified the components of inquiry-based teaching that foster critical thinking development. After each video, the participants briefly discussed their responses in small groups.

III. 40 minutes: The participants worked collaboratively to brainstorm ideas for inquiry-based lessons to be implemented in their subject areas. The participants used the Science Lesson Template (Appendix C), developed by the researcher, to design and implement a lesson that incorporates the inquiry components that cultivate critical thinking.

IV. Homework: The participants used the “Criteria for Critical Thinking” and “Critical Thinking Grid” (Foundation for Critical Thinking, 2015) instructional tools to develop, implement in their classes, and evaluate a critical thinking assignment prior to PD workshop three.
Professional development workshop #3. The primary objectives of the third PD workshop were as follows: (1) to review the critical thinking concepts covered in the first two workshops, namely the elements of thought, the universal intellectual standards (Paul & Elder, 2009), and inquiry-based learning; (2) to provide an overview of problem-based learning using “A Template for Problem-Solving” (Paul & Elder, 2009) and a video lesson from TeacherChannel.org; (3) to model problem-based learning by performing a group activity; and, (4) to work collaboratively to design lessons that incorporate problem-based learning, the universal intellectual standards, and the elements of thought (Paul & Elder, 2009) to promote critical thinking development.

The following provides the agenda for the PD workshop three activities implemented in an effort to meet each of the aforementioned objectives:

I. 10 minutes: The researcher used a PowerPoint to introduce problem-based learning (PBL) as an example of an effective student-centered strategy for cultivating critical thinking.

II. 20 minutes: The participants watched PBL in action by viewing two short videos of science lessons from TeachingChannel.org: “Energy & Matter across Science Disciplines” and “Using Engineering Design in the Classroom.” During each video, using a worksheet (Appendix C) developed by the researcher and provided in the information packet, the participants identified the components of PBL that foster critical thinking development. After each video, the participants briefly discussed their responses in small groups.
III. 45 minutes: To gain hands-on experience with PBL, the participants worked in teams to solve a problem adapted from the TeachingChannel.org video lesson, “Problem Solving under Pressure.” The activity required the teacher teams to use materials provided to solve an authentic engineering problem. The participants were encouraged to apply the learned strategies for maximizing their critical thinking development. After 30 minutes, the teams discussed their problem-solving strategies and the activity components that fostered critical thinking development.

IV. 15 minutes: The participants worked collaboratively to brainstorm ideas for problem-based lessons to be implemented in their subject areas. The participants used the Science Lesson Template (Appendix C) to design lessons that cultivate critical thinking. The problem-based lesson would be used for the next observation, to be completed by a peer from the treatment group.

V. The researcher assigned participants to a peer (another treatment group participant) for the next peer observation, to be conducted within the next two weeks. For each participant, the peer assigned for the second observation was the same peer that performed the first observation.

VI. Homework: The participants used the “Criteria for Critical Thinking” and “Critical Thinking Grid” (Foundation for Critical Thinking, 2015) instructional tools to develop, implement in their classes, and evaluate a critical thinking assignment prior to *PD workshop four*. They were asked
to bring to the next PD workshop a student work sample from the critical thinking assignment.

**Professional development workshop #4.** The primary objectives of the fourth PD workshop were as follows: (1) to review the critical thinking concepts covered in the previous workshops; (2) to collaboratively discuss and reflect on the peer observation experience and areas for professional growth; (3) to finish learning the content from “The Miniature Guide to Critical Thinking Concepts and Tools” (Paul & Elder, 2009) by discussing the connection between the universal intellectual standards, the elements of thought, and intellectual traits; and, (4) to collaboratively reflect on the effectiveness of the critical thinking assignments developed in *PD workshop one* and the “Critical Thinking Grid” by evaluating student work samples.

The following provides the agenda for the *PD workshop four* activities implemented in an effort to meet each of the aforementioned objectives:

I. **10 minutes:** The researcher used a PowerPoint to review the components of critical thinking instruction and problem-based learning.

II. **20 minutes:** The researcher asked the participants to collaboratively discuss and reflect on the effectiveness of their problem-based lessons based on the RTOP feedback, areas of their instruction to be targeted for improvement, and ideas for adapting their problem-based lesson in the future to be more in alignment with critical thinking instruction. To facilitate their discussion, the participants were provided with the following prompts:
a. In what ways did your lesson incorporate problem-based learning or other critical thinking strategies? Did the lesson incorporate any critical thinking concepts (i.e., elements of thought; universal intellectual standards)? If so, what evidence do you have that you incorporated these concepts?

b. After reflecting on your lesson and the RTOP feedback, what components of the lesson do you believe best supported the students’ critical thinking development?

c. After reflecting on the lesson and the RTOP feedback, how would you change your lesson in the future to better support students’ critical thinking?

d. What were the greatest challenges to aligning your lesson with implementing critical thinking practices?

e. After the observation experiences thus far, how have your views about critical thinking instruction changed? What questions or concerns do you still have about critical thinking instruction?

III. 30 minutes: The participants discussed one of the critical thinking assignments they created (using the “Criteria for Critical Thinking Assignments”) and implemented in their classes. First, they reflected individually on the assignment by answering the questions provided on the PD Workshop Four handout (Appendix C). Second, in groups of four, the participants shared student work samples from the lessons that they evaluated using the “Critical Thinking Grid” (Foundation for Critical
Thinking, 2015). Third, they discussed the components of the assignments that promoted critical thinking, the challenges encountered in using the rubric, and the students’ overall application of critical thinking skills in the assignments. To facilitate their discussion, the following discussion prompts were included on the handout in the information packet:

a. Discuss how the assignment incorporated the universal intellectual standards, elements of thought, problem-based learning, inquiry-based learning, and/or other critical thinking components that promote the use of higher-order cognitive skills.

b. Based on the students’ performance (using the “Critical Thinking Grid”), how effective was the assignment in promoting the students’ use of critical thinking skills?

c. Discuss the different ways in which the assignments fostered the students’ use of critical thinking. What components of the assignment do you believe most effectively fostered the students’ critical thinking?

d. Compare the student work samples on display. What evidence of critical thinking is apparent in the student work samples?

e. How might you change the assignment in the future to encourage the students’ increased application of critical thinking skills? How could you adapt this assignment for other science topics or units?

f. Discuss the aspects of the assignment process that you found to be most challenging (e.g., the design process, the implementation process,
the grading/evaluation process, etc.). What might you do differently in the future to address these challenges?

IV. 10 minutes: The researcher used the PowerPoint to review inquiry-based learning and the components of critical thinking (Paul & Elder, 2009).

V. 20 minutes: To conclude the workshop, the participants worked collaboratively in groups of four to create concept maps that demonstrated their understanding of the relationships between Paul and Elder’s (2009) critical thinking concepts and the strategies (inquiry- and problem-based learning) learned in the PD workshops.

VI. The participants were instructed to complete the post-intervention survey on SurveyMonkey.com within the next two weeks.

**Overview of mentoring sessions.** Mentoring sessions, led by the researcher, took place at four time points during the intervention: after the first observation cycle (before PD workshop one), after the second observation cycle (before PD workshop two), after the second PD workshop (before PD workshop three), and after the third observation cycle (before PD workshop four). Each 30-minute mentoring session was attended by the researcher and one to two treatment group participants (see observation protocol). In each mentoring session, the researcher and the participants collaboratively reflected on the in-depth, RTOP observation feedback and brainstormed strategies for improving the participants’ critical thinking instructional practice.

For the first round of mentoring sessions, the researcher met one-on-one with each treatment group participant. In addition to providing the participant with the observation feedback, the researcher used this session to discuss with the participant the
RTOP instrument and how it is used to assess the teacher’s lesson and critical thinking pedagogy. In particular, the researcher discussed in depth each RTOP subscale, how the items in each subscale were scored, and why the subscales serve as effective indicators of critical thinking instruction. The researcher then recommended strategies that would increase the participant’s score for each of the RTOP subscales. For each of the second, third, and fourth mentoring sessions, the researcher met with two treatment group participants assigned to one another for the peer observations. During each of these mentoring sessions, the participants shared with their peer the RTOP feedback on the peer’s lesson and suggestions for improvement. In addition, the researcher provided the participants with support by contributing further insight and strategies for enhancing the participants’ critical thinking instructional approaches. While these mentoring sessions benefitted the participants by providing them with opportunities to collaboratively discuss and reflect on their professional practice, the group nature of the sessions limited the researcher’s ability to attribute any qualitative findings gathered during these sessions to an individual participant. However, the collaborative nature of these sessions permitted more in-depth discussion of the participants’ professional practice and lesson improvement strategies than would have been provided by one-on-one mentoring sessions.

The following table provides a timeline and schedule of the intervention activities:
Table 2

*Schedule of Intervention Activities*

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
</table>
| **September 2016** | Pre-Intervention Classroom Observations (by researcher) using RTOP  
Pre-Intervention Survey (*Treatment & Control Groups*)  
Pre-Intervention Course Evaluations (*Students*)  
Mentoring Session #1  
Professional Development Workshop #1 (*Treatment Group*) |
| **October 2016** | Peer Observations using RTOP  
Mentoring Session #2  
Professional Development Workshop #2  
• Participants submit completed “Criteria for Critical Thinking Assignments” template #1 and student work samples (*Treatment Group*) |
| **November 2016** | Mentoring Session #3 |
| **January 2017** | Professional Development Workshop #3  
• Participants submit completed “Criteria for Critical Thinking Assignments” template #2 and student work samples (*Treatment Group*) |
| **February 2017** | Peer Observations using RTOP  
Mentoring Session #4  
Professional Development Workshop #4  
• Participants submit completed “Criteria for Critical Thinking Assignments” template #3 and student work samples (*Treatment Group*) |
| **March 2017** | Post-Intervention Classroom Observations (by researcher) using RTOP  
Post-Intervention Survey (*Treatment & Control Groups*)  
Post-Intervention Interview (*Treatment Group*)  
Post-Intervention Course Evaluations (*Students*) |
Evaluation Questions

1. To what extent do the dose and quality of the delivered intervention components adhere to the theory-driven intervention elements illustrated in the logic model and theory of treatment?

2. To what extent does participation in the different intervention components lead to a positive change in the teachers’ knowledge of critical thinking instructional practices?

3. To what extent does participation in the different intervention components lead to a positive change in the teachers’ pedagogical beliefs about critical thinking instructional practices?

4. To what extent does participation in the intervention components lead to increased teacher adoption of critical thinking instructional practices?

Data Collection

In order to determine the fidelity of implementation and effectiveness of the study in increasing the teacher participants’ adoption of critical thinking instructional practices, process and outcome evaluations were performed. The following sections discuss the types of data collected as part of the process evaluation (to assess the fidelity of implementation) and outcome evaluation (to assess the study’s effectiveness in producing the desired outcomes).

Process Evaluation

The effectiveness of an intervention is frequently determined via the analysis of outcome measures that indicate the extent to which the intervention objectives were achieved (Nelson, Cordray, Hulleman, Darrow, & Sommer, 2012). For example, with
regard to the professional development intervention, the extent to which the teacher participants adopted critical thinking instructional practices served to indicate the program’s effectiveness. However, numerous factors influence a program’s observed outcomes and overall effectiveness. Among the most influential of these factors is the fidelity of implementation, or “the degree to which teachers and other program providers implement programs as intended by the program developers” (Dusenbury, Brannigan, Falco, & Hansen, 2003, p. 240). Understanding the fidelity of implementation enables researchers to determine the extent to which the program as implemented aligns with the program as designed. In addition, by assessing fidelity, the “black box” components that most contribute to the observed treatment effects can be identified (Nelson et al., 2012). Ultimately, by thoroughly evaluating the intervention process and its fidelity of implementation, researchers determine its likely effectiveness and scale-up potential in other settings (Saunders et al., 2005).

In order to determine the fidelity of the intervention, the researcher evaluated the extent to which the different components of the professional development program aligned with the logic model (Appendix A) and theory of treatment (Appendix A). The logic model illustrates the step-wise progression and causal links between the inputs, activities, mediators, and outcomes expected to be observed in the treatment group. The theory of treatment provides the theoretical basis for the expected progression between the intervention causes (inputs, activities) and desired effects (mediators, outcomes). Implemented as intended, the theory-driven intervention components are expected to positively influence the mediators (the teacher participants’ knowledge and beliefs about critical thinking pedagogy) and the desired short-term outcome (teacher participants’
adoption of critical thinking instructional practices). Therefore, in an effort to deeply understand the etiology of the observed effects and thus the program’s overall effectiveness, the program’s fidelity of implementation was determined by performing a process evaluation (Saunders et al., 2005).

The purpose of the intervention was to increase the teacher participants’ adoption of critical thinking instructional practices. Because the logic model provides a theory-driven framework for supporting teachers’ transition to reform-oriented practices, a program with high fidelity is more likely to produce the desired outcomes than a program with low fidelity (Holliday, 2014). An intervention with high fidelity will: adhere to the critical elements of the program (mentoring provided by the researcher, in-depth feedback on classroom instruction, collaboration between the participants, and reflection on pedagogical practices), provide all of the treatment group participants with the recommended dose (four professional development workshops and four mentoring sessions), effectively deliver the program components (provide relevant resources and training in critical thinking instruction, perform observations, and provide feedback on instruction), deeply engage participants in the program activities, and differentiate the program such that the treatment group receives program elements distinct from those received by the control group. For the purpose of the intervention, a program with low fidelity is characterized by lacking one or more of the aforementioned features, as it is the combination of these theory-based components that is expected to produce the desired outcomes.

While maintaining high fidelity helps to ensure the program’s internal and external validity, some interventions achieve the desired outcomes in the absence of high
fidelity (Holliday, 2014). In an independent school setting, it may be necessary to adapt the intervention in order to overcome the school’s unique cultural and contextual constraints. Therefore, measuring the fidelity of implementation will provide insight into the level of adaptation permitted while still achieving the desired outcomes and maintaining the program’s validity (Dusenbury et al., 2003).

**Fidelity of implementation: Indicators.** The fidelity of implementation, or the extent to which the program as implemented aligns with the program as designed, was assessed using qualitative and/or quantitative measures for each fidelity component: adherence, dose, quality of delivery, participant responsiveness, and program differentiation.

**Adherence.** In order to assess the fidelity of implementation, the critical components of the intervention must first be identified. For example, regarding the intervention, the critical elements, or those essential to the success of the program, included the following activities illustrated in the logic model: PD workshops on critical thinking instruction, mentoring provided by the researcher, implementation of critical thinking assignments, collaboration between the treatment group members, observations of classroom practice (using RTOP), and reflection on the RTOP feedback and instructional practice. With the critical elements identified, the extent to which the intervention as implemented adhered to the intervention as planned could be assessed (Dusenbury et al., 2003).

In order to assess the intervention’s adherence, the teacher participants completed templates that reflected the activities performed and information learned in each session. These templates were maintained in the information binder and include: (1) the “Criteria
for Critical Thinking Assignments” (Foundation for Critical Thinking, 2015); (2) the “Critical Thinking Grid” (Foundation for Critical Thinking, 2015); (3) Science Lesson templates; and, (4) reflection questions for Reinhart’s (2000) “Never Say Anything a Kid Can Say!” article. Additionally, the RTOP feedback served as an indicator that regular observations, a critical program component, were performed during the intervention.

**Dose.** In addition to adherence, the fidelity of implementation is assessed by measuring the dose, or “the amount of program content received by participants” (Dusenbury et al., 2003, p. 241). Indicators of dose measure the number and duration of sessions delivered to, or received by, the participants. According to the logic model for the intervention, the treatment group participants would need to attend four professional development workshops (90 minutes each) and four mentoring sessions (30 minutes each), be observed by a peer or the researcher on four separate occasions (40 minutes each), and conduct two peer observations (40 minutes each) in order to receive the level of treatment recommended to produce the desired outcomes (Desimone et al., 2002; Elder, 2005; Garet et al., 2001; Park et al., 2015). Therefore, as an indicator of the dose received by the participants, the researcher maintained an attendance log at each of the professional development and mentoring sessions. In addition to acknowledging their attendance at the sessions, the participants also recorded the duration of each of the sessions attended. In the event that a participant was absent from a PD workshop, the session was audio-recorded so that the participant would have a means of learning the content covered in the workshop. The RTOP feedback served to indicate that the observations of the participants’ classes were performed at the required frequency and within the designated timeframe.
Quality of delivery. The quality of delivery is defined as “ratings of provider effectiveness which assess the extent to which a provider approaches a theoretical ideal in terms of delivering program content” (Dusenbury et al., 2003, p. 244). As illustrated in the logic model and theory of change diagram, the effective delivery of the intervention activities was expected to produce positive change in the mediating variables: teachers’ pedagogical beliefs and knowledge. Therefore, indicators that measured change in the mediating variables were used to assess the quality with which the program components were delivered. For example, a critical element of the professional development program was the delivery of the RTOP observation feedback to the treatment group members. In order to determine the quality with which this information was delivered, the post-intervention survey and interviews with the participants assessed: 1) the degree of the participants’ perceived change in pedagogical knowledge and beliefs, and 2) the extent to which they attributed this change to the delivery of specific components of the program, including the RTOP observation feedback.

Participant responsiveness. An additional indicator of fidelity of implementation is participant responsiveness, defined as “the extent to which participants are engaged by and involved in the activities and content of the program” (Dusenbury et al., 2003, p. 244). In the intervention, participant responsiveness was measured directly via the post-intervention survey in which the teachers rated their level of involvement in specific program components. For example, according to the theory of treatment, teacher engagement in the reflection component of the program was expected to produce positive change in the mediating variables of pedagogical beliefs and knowledge (Duzor, 2011).
Therefore, the post-intervention survey asked the treatment group participants to rate their level of engagement in the reflection component of the program.

Additionally, because the adoption of student-centered pedagogical beliefs is often reflected in teachers’ classroom practice (Ertmer et al., 2012), participant responsiveness was measured indirectly via formal classroom observations performed by the researcher on two occasions: once before and once after the intervention. Also, participant responsiveness was indirectly measured via the collection of the “Criteria for Critical Thinking” templates for three assignments designed by the treatment group participants, and also by the evaluation of student work samples for each assignment using the “Critical Thinking Grid” (Foundation for Critical Thinking, 2013). Also, participant responsiveness was measured indirectly via the pre- and post-intervention administration of the “Course Evaluation” form (Foundation for Critical Thinking, 2007) to the students in the participants’ classes. The classroom observations (using RTOP), the critical thinking assignments, and the course evaluations provided evidence of the teacher participants’ application of the promoted critical thinking practices and thus the teachers’ level of engagement in the program components that provided training in these practices.

Program differentiation. Finally, the fidelity of implementation was further assessed via program differentiation, or the process of “identifying unique features of different components or programs so that these components or programs can be reliably differentiated from one another” (Dusenbury et al., 2003, p. 244). Measuring program differentiation was especially important for assessing the fidelity of the intervention implemented within the Science Department at ICS. Because both the treatment group and control group members are teachers in the Science Department, they worked closely
with one another on a daily basis and attended the same school-wide meetings and professional development sessions. These frequent interactions between the treatment and control group members increased the likelihood that the control group would be “contaminated” (p. 147) with the treatment conditions, thus increasing the risk for a Type II error (Wholey, Hatry, & Newcomer, 2010).

In order to demonstrate the superior effectiveness of the components received by the treatment group when compared to those received by the control group, it was essential that the intervention deliver unique, critical elements that would be received solely by the treatment group members, and that these elements not diffuse to the control group (Wholey et al., 2010). Therefore, a post-intervention, open-ended interview conducted by the researcher with the participants inquired about the program components that most contributed to any perceived change in their pedagogical beliefs, knowledge, and practice. Also, the post-intervention survey administered to the treatment group members included questions that assessed the extent to which information about the program components was shared with control group members.
Table 3

Data Collection Matrix – Process Evaluation

<table>
<thead>
<tr>
<th>Fidelity Indicator</th>
<th>Data Source(s)</th>
<th>Data Collection Tool</th>
<th>Frequency</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence of program components with program design</td>
<td>Teacher Participants (treatment group)</td>
<td>RTOP Observation Instrument</td>
<td>2×(pre- and post-intervention)</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Dose: Attendance at PD sessions</td>
<td>Teacher Participants (treatment group)</td>
<td>Attendance Log</td>
<td>4× (teachers sign-in at each PD session)</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Quality of delivery of program components</td>
<td>Teacher Participants (treatment group)</td>
<td>Survey</td>
<td>1× (post-intervention)</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Quality of delivery of program components</td>
<td>Teacher Participants (treatment group)</td>
<td>Interview</td>
<td>1× (post-intervention)</td>
<td>Qualitative Coding</td>
</tr>
<tr>
<td>Participant Responsiveness: Level of Engagement in PD components</td>
<td>Teacher Participants (treatment group)</td>
<td>Survey</td>
<td>1× (post-intervention)</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Participant Responsiveness: Level of engagement in PD components</td>
<td>Teacher Participants (treatment group)</td>
<td>RTOP (Observation instrument)</td>
<td>2× (pre- and post-intervention)</td>
<td>T-Tests</td>
</tr>
<tr>
<td>Participant Responsiveness: Level of engagement in PD components</td>
<td>Students</td>
<td>Critical Thinking Grid</td>
<td>3× (during intervention)</td>
<td>MANOVA</td>
</tr>
<tr>
<td>Program Differentiation: Treatment (PD) vs. control group</td>
<td>Teacher Participants (treatment group)</td>
<td>Interview</td>
<td>1× (post-intervention)</td>
<td>Qualitative Coding</td>
</tr>
</tbody>
</table>
Outcome Evaluation

The purpose of the outcome evaluation was to measure the intervention’s effectiveness in achieving the desired outcome: the teachers’ increased adoption of student-centered instructional practices that cultivate students’ critical thinking skills. If the intervention treatments were administered as planned, then the majority of the treatment group participants should increase their adoption of the promoted critical thinking instructional practices, as indicated by an effect size of 0.42 or above. Using a pretest-posttest control group design, the treatment effect was determined by comparing the data collected from the treatment group to the data collected from the control group at pre-, mid-, and post-intervention. By having a control group against which to compare the treatment group’s data, any observed effects could more likely be attributed to the treatment instead of random change that might have occurred in the absence of the intervention.

Effect size. In order to have practical significance, the intervention must ideally attain an effect size with a minimum magnitude of 0.42. Based on the findings of two similar studies (Boston & Smith, 2009; Fulmer & Liang, 2012), the researcher expected that an effect size of 0.42 would be attainable given the nature and context of the intervention.

Boston and Smith (2009) report the findings from their study that investigated the effects of a professional development intervention on 18 secondary mathematics teachers’ use of cognitively-demanding instructional tasks. During the 2004-2005 school year, teachers in the treatment group participated in 6 days of professional development workshops as part of the Enhancing Secondary Mathematics Teacher Preparation (ESP)
program (Boston & Smith, 2009). Similar to the PD program which used a research-based framework (Foundation for Critical Thinking, 2015) to guide the PD activities, the ESP program also followed a research-based framework: The Mathematical Tasks Framework (Stein, Smith, Henningsen, & Silver, 2000). In addition, the primary objective of both the PD intervention and the ESP program was to increase the teachers’ implementation of cognitively-demanding instructional tasks (Boston & Smith, 2009).

Finally, similar to the PD intervention, the ESP program included elements intended to increase the teachers’ implementation of the promoted instructional practices. For example, the ESP program provided the participants with meaningful and authentic learning opportunities related to their classroom teaching. Also, during the PD workshops, the participants worked collaboratively to analyze instruction viewed in video lessons and student work (Boston & Smith, 2009).

For their study, Boston and Smith (2009) collected data at three time points: once during the fall (at the beginning of the ESP program), once during the winter, and once during the spring (at the end of the ESP program). The data collected – including formal observations of the participants’ lessons, the teachers’ lesson checklists, and student work – revealed the cognitive demand of the instructional tasks implemented by the teachers in the treatment group. According to the analyses, the cognitive demand of the teachers’ lessons at the winter time point (the intervention’s half-way point) was significantly higher than the cognitive demand of the lessons at the fall time point. Similar to the desired outcome of the PD study, these results indicate the participants’ increased adoption of cognitively-demanding instructional approaches. Further, these significant results were obtained after the completion of just three of the six PD workshops. After
completion of three of the ESP workshops (at the winter time point), the magnitude of the effect size in regards to the teachers’ implementation of the promoted instructional tasks was 0.42 (n = 11; p < 0.05). Because this PD intervention entailed participation in four workshops that included features similar to those of the ESP program, it was expected to attain a similar effect size (r = 0.42) as the Boston and Smith’s (2009) study.

In a related study, Fulmer and Liang (2012) report findings related to the effects of a professional development program on high school science teachers’ instruction. The participants (n = 72) attended a three-week summer workshop that aimed to increase the teachers’ use of inquiry-based instructional practices. Similar to the PD intervention, the PD summer workshop presented in the article modeled best practices by: informing the teachers of research in science pedagogy, providing ample time for the teachers to practice the promoted instructional strategies, and, encouraging the teachers to collaboratively reflect on and analyze pedagogical approaches in an effort to improve their own instructional practice. Also, similar to the program presented in the study, the PD program promotes the participants’ use of inquiry-based learning practices.

According to the study results, when compared to the control group members who did not participate in the summer PD program, the treatment group members increased their use of inquiry-based instructional approaches (r = 0.43).

Similar to the aforementioned studies, the PD intervention aimed to increase high school teachers’ use of student-centered instructional practices that cultivate students’ critical thinking. Because the effect sizes were based on similar studies that measured the impact of a PD program on high school teachers’ use of instructional strategies, they provided a target effect size (0.43) that was potentially attainable within the context of
the intervention (Hill et al., 2008). However, whereas 68 subjects were needed to detect the minimum effect size (with $\alpha = 0.05$ and power = 0.80), only 15 subjects were available to participate in the study. Therefore, in order to increase the sensitivity to intervention effects, statistical power was maximized via an analysis approach that increased the signal-to-noise ratio (Lipsey, 1998). In particular, the use of valid and reliable measures that are responsive to change in teachers’ critical thinking instructional practice enhanced the statistical power by increasing the “signal” (and decreasing the “noise”) and, therefore, the magnitude of the effect size (Lipsey, 1998). For example, in the study, the formal observations that took place outside of the workshops aimed to provide additional support for promoting the participants’ adoption of the learned critical thinking strategies. The participants not only received in-depth, RTOP feedback on their instruction, but they also engaged in peer observations that enhanced their understanding of the critical thinking instructional practices learned in the PD workshops. Furthermore, outside of the PD workshops, the study participants gained additional practice in implementing the promoted instructional practices by designing and evaluating assignments that required their students’ application of critical thinking skills. Therefore, by engaging the participants in activities embedded in both the PD workshops and their classroom environment, the intervention was expected to produce the desired effect size of $r = 0.43$.

**Evaluation design.** Within the Science Department at ICS, a pretest-posttest control group design (Shadish et al., 2002) was used to determine the impact of the professional development program on the teacher participants’ adoption of critical thinking instructional practices. In particular, using the pretest-posttest control group
design, the effects of the treatment on the mediating, moderating, and outcome variables were assessed. This particular design enhanced the researcher’s ability to link cause and effect; if negligible differences in the measured variables existed between the treatment and control groups at pretest, then any observed effects at posttest could be attributed to the treatment (Shadish et al., 2002).

**Mediating and moderating variables.** Using a pretest-posttest control group design, data were collected pre- and post-intervention to indicate the impact of the intervention on the desired short- and medium-term outcomes. In particular, the intervention treatment was expected to influence the teachers’ knowledge of critical thinking instructional practices, an important mediating variable that is positively associated with teachers’ implementation of critical thinking instructional strategies (Desimone et al., 2002; Paul & Elder, 2002). In addition, the intervention outcomes would likely be influenced by the teachers’ pedagogical beliefs, a moderating variable positively associated with teachers’ instructional practice (Ertmer et al., 2012). Therefore, measures that assessed change in the teachers’ pedagogical knowledge and beliefs were used to indicate the impact of the intervention treatment on these variables. Specifically, at pretest, a survey administered to the treatment and control group participants assessed their existing pedagogical knowledge and beliefs prior to the intervention. Then, at posttest, a similar survey administered to the treatment and control group participants assessed their pedagogical knowledge and beliefs following the intervention. By comparing the participants’ responses on the pre- and post-intervention surveys, the impact of the intervention on the mediating and moderating variables could be assessed. A significant increase in either the teachers’ pedagogical knowledge or beliefs in favor of
critical thinking instruction was expected, in turn, to positively influence teachers’
adoption of critical thinking instructional practices (Ertmer et al., 2012).

**Outcome variable.** In order to measure the impact of the treatment on the desired
outcome variable (teachers’ adoption of critical thinking instructional practices), the
RTOP instrument was used pre- and post-intervention to collect data on the participants’
classroom implementation of the promoted practices. The RTOP is a valid and reliable
instrument for measuring the effectiveness with which teachers implement research-
based, student-centered instructional strategies that cultivate critical thinking skills
(Sawada et al., 2002). A comparison of the treatment and control groups’ pre- and post-
intervention mean RTOP ratings would thus reveal the impact of the intervention on the
teachers’ implementation of critical thinking instructional practices.

In addition, the degree to which the teacher participants adopted critical thinking
instructional practices was measured via the administration, pre- and post-intervention, of
the “Course Evaluation Form” (Foundation for Critical Thinking, 2007) to the students in
the treatment and control group participants’ science classes. The “Course Evaluation
Form” is a Likert-style questionnaire in which the student rates on a scale of 1 to 5 (1 =
“low score” and 5 = “high score”) the teacher’s use of instructional strategies that foster
critical thinking (Foundation for Critical Thinking, 2007). Therefore, a comparison of the
treatment and control groups’ pre- and post-intervention student ratings on the “Course
Evaluation Form” served to further indicate the extent to which the intervention produced
the desired outcome: teachers’ adoption of critical thinking instructional practices.

Furthermore, the degree to which the teacher participants adopted critical thinking
instructional practices was measured via the use of the “Critical Thinking Grid” tool
(Foundation for Critical Thinking, 2015). At three time points during the intervention (after the first PD workshop, after the second PD workshop, and after the third PD workshop), the treatment group participants designed and implemented assignments following the criteria stated on the “Criteria for Critical Thinking Assignments” tool. Then, following the implementation of the critical thinking assignments in their classes, the participants collected and evaluated the students’ work using the “Critical Thinking Grid”. The researcher also collected and evaluated (using the “Critical Thinking Grid”) student work samples for assignments that the control group participants assigned in their classes at the same three time points. The control group participants were not provided the “Critical Thinking Grid” during the intervention. A comparison of the students’ assignment scores (using the “Critical Thinking Grid”) from the treatment and control groups’ classes at each time point provided an indication of whether the participants increased their adoption of critical thinking instructional practices over time.
Table 4

Data Collection Matrix – Outcome Evaluation

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Evaluation Question #</th>
<th>Role of Indicator</th>
<th>Data Sources</th>
<th>Frequency</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers’ Adoption of CT Instruction (Tool: RTOP)</td>
<td>4</td>
<td>Outcome Variable</td>
<td>Treatment &amp; Control Groups</td>
<td>$2 \times \ (pre\text{-} and\text{-}post\text{-}intervention)$</td>
<td>ANCOVA</td>
</tr>
<tr>
<td>Teachers’ Adoption of CT Instruction (Tool: Course Evaluation Form)</td>
<td>4</td>
<td>Outcome Variable</td>
<td>Students</td>
<td>$2 \times \ (pre\text{-} and\text{-}post\text{-}intervention)$</td>
<td>ANCOVA</td>
</tr>
<tr>
<td>Teachers’ Adoption of CT Instruction (Tool: CT Grid)</td>
<td>4</td>
<td>Outcome Variable</td>
<td>Students</td>
<td>$3 \times \ (during\ intervention)$</td>
<td>MANOVA, Linear Regression</td>
</tr>
<tr>
<td>Teachers’ Adoption of CT Instruction (Tool: Interview)</td>
<td>4</td>
<td>Outcome Variable</td>
<td>Treatment Group</td>
<td>$1 \times \ (post\text{-}intervention)$</td>
<td>Qualitative Coding</td>
</tr>
<tr>
<td>Knowledge of CT Instructional Strategies (Tool: Survey)</td>
<td>2</td>
<td>Mediating Variable</td>
<td>Treatment &amp; Control Groups</td>
<td>$2 \times \ (pre\text{-} and\text{-}post\text{-}Intervention)$</td>
<td>ANCOVA, MANOVA</td>
</tr>
<tr>
<td>Pedagogical Beliefs (Tool: Survey)</td>
<td>3</td>
<td>Moderating Variable</td>
<td>Treatment &amp; Control Groups</td>
<td>$2 \times \ (pre\text{-} and\text{-}post\text{-}Intervention)$</td>
<td>ANCOVA, MANOVA</td>
</tr>
<tr>
<td>Teaching Subject Area (Tool: Survey)</td>
<td>N/A</td>
<td>Control Variable</td>
<td>Treatment &amp; Control Groups</td>
<td>$1 \times \ (pre\text{-}intervention)$</td>
<td>Descriptive</td>
</tr>
</tbody>
</table>
Data Analysis

Quantitative Data Analysis

**RTOP observation instrument.** The classroom observation data were scored via the use of the RTOP instrument. The RTOP scores from each observation were categorized into one of the following five categories: level I (15-30), level II (31-45), level III (46-60), level IV (61-75), and level V (76-100). Descriptive statistics were used to calculate the mean RTOP level for the treatment group and the control group. For the treatment group, the mean RTOP level for the formal observations performed at each time point (pre- and post-intervention) provided an indication of the adherence of the intervention’s components with the intervention’s design. To determine the effect of the intervention on the participants’ RTOP level, univariate analyses were used to compare the treatment group’s RTOP scores to the control group’s RTOP scores.

**Survey.** Descriptive statistics were used to calculate the mean scores for the pre- and post-intervention surveys administered to the treatment and control groups. The mean survey scores served to indicate the intervention dose received by the participants, the quality of the delivered intervention components, and the level of the participants’ engagement in the different intervention components. To determine the effect of the intervention on the participants’ knowledge of critical thinking instruction and beliefs about critical thinking pedagogical approaches, multivariate analyses were performed to compare the mean survey scores from the treatment group and the control group.

**Critical thinking grid.** Descriptive statistics were used to calculate the participants’ students’ mean scores on the “Critical Thinking Grid” tool (Foundation for Critical Thinking, 2015) completed at three time points: between PD workshops one and
two, between PD workshops two and three, and between PD workshops three and four. Multivariate and linear regression analyses were performed to compare the students’ scores over time. A comparison of the students’ mean scores at each time point served to indicate both the level of the participants’ engagement in the PD components and their level of adoption of critical thinking instructional practices over time.

**Course evaluation form.** Descriptive statistics were used to calculate the mean scores on the “Course Evaluation Form” (Foundation for Critical Thinking, 2015) administered to the students in the participants’ classes pre- and post-intervention. To determine the effect of the intervention on the students’ evaluations of their teachers’ instructional practice, univariate analyses were performed to compare the treatment group’s evaluation scores to the control group’s evaluation scores. The difference between the mean evaluation scores provided an indication of the extent to which the participants’ adopted critical thinking instructional approaches after participating in the intervention.

**Qualitative Data Analysis**

**Interview.** The participants’ interview responses were recorded and coded to identify patterns and themes relating to their understanding and practice of critical thinking instruction. In-depth examination of the raw interview data revealed patterns in the participants’ responses that, through first and second cycle coding methods, led to the emergence of categories and themes that characterized the data (Saldana, 2016). In order to ensure the most accurate and thorough analyses, the specific coding methods were selected upon initial review of the raw data (Saldana, 2016). However, given the nature of the research questions, first cycle coding methods expected to reveal the participants’
level of understanding and perceptions of critical thinking instruction included:

“Descriptive, Process, Initial, Versus, Evaluation, Dramaturgical, Domain and Taxonomic, Causation, and/or Pattern Coding, plus Theming the Data” (Saldana, 2016, p. 70). Second cycle coding methods served to refine and categorize the coded data into emerging themes (Saldana, 2016). The first and second cycle coding methods were expected to elucidate key themes regarding the participants’ understanding of: critical thinking development, the components of critical thinking, how critical thinking is applied in the sciences, how critical thinking is fostered in the classroom, and obstacles to the more frequent implementation of critical thinking instruction. Based on the literature, the following are examples of codes that the researcher expected to emerge from the first and second coding cycles: (1) critical thinking development: analysis, evaluate, quality, reason, highest-order thought; (2) critical thinking components: elements of thought, intellectual standards, point of view, purpose, question, information, interpretation, concepts, assumptions, implications; (3) critical thinking application in the sciences: inquiry, problem-based, investigate, collaborate; (4) fostering critical thinking in the classroom: elements of thought, collaboration, reflection, inquiry, problems, questioning, intellectual standards, assignments, cognitive skills; and, (5) obstacles: time, content, curriculum, support, training, evaluations.

The first and second cycle coding methods were also expected to reveal the key intervention components that most influenced the participants’ perceptions, understanding, and practice of critical thinking instruction. Examples of intervention components that the researcher expected the participants to identify include: mentoring, PD workshops, collaboration with peers, observations, RTOP feedback, critical thinking
assignments, and reflection on instruction. An analysis of the frequency with which the participants identified specific intervention components revealed those components that most influenced any observed changes in the participants’ knowledge, pedagogical beliefs, and/or instructional practice.

**Conclusion**

In summary, the professional development intervention incorporated elements expected to produce the desired short- and medium-term outcomes illustrated in the logic model (Appendix A). In particular, the key components of the intervention, namely mentoring by the researcher, PD workshops, peer collaboration, classroom observations, and reflection on instruction, were expected to produce positive changes in the participants’ knowledge of and pedagogical beliefs about critical thinking instructional practices (short-term outcomes). In turn, via a causal chain, these positive changes in pedagogical beliefs and knowledge were expected, within the intervention timeframe, to increase the participants’ adoption of critical thinking instructional practices (medium-term outcome). Process and outcome evaluations assessed the fidelity of implementation and the effectiveness of the intervention components in promoting the participants’ adoption of critical thinking instructional practices.
Chapter 5

Process of Implementation and Findings

Recruitment

Recruitment for the research study began in August 2016. In order to inform the science department members of the study, the researcher sent the potential participants via email the recruitment letter approved by the Johns Hopkins’ Internal Review Board. The science department members received the letter in August prior to the start of the school year. During the science department’s first formal meeting in August, the researcher followed-up with the department members by providing additional information about the study components and the recruitment protocol. All 15 of the science department members were present at the meeting. The researcher requested that any department members interested in participating in the study should carefully read over and sign the informed consent form within the next two weeks. The researcher also encouraged the department members to stop by her office should they have any questions or concerns or need further clarification of the study requirements.

Within two weeks of informing the science department members of the research study, all 15 science department members volunteered to participate in either the treatment group or the control group. Ten department members expressed interest in participating in the treatment group and submitted a signed informed consent form agreeing to full participation in the study components. These department members were especially eager to learn novel instructional approaches that would enhance their professional practice. Five department members expressed interest in participating in the control group and also submitted a signed informed consent form agreeing to
participation in the requisite study components. While these department members were also eager to learn novel instructional approaches, they felt their existing teaching responsibilities would prohibit their full participation in the requisite intervention components.

The 10 treatment group participants included eight high school and two middle school science teachers. Among the high school participants were two biology teachers, two chemistry teachers, one physics teacher, two engineering teachers, and one environmental science teacher. The experience level of participants in the treatment group ranged from novice to veteran, with five of the participants being fairly new to the teaching profession (zero to five years’ teaching experience) and five of the participants possessing many years (10 to 25) of teaching experience.

The five control group participants included: two biology teachers, one chemistry teacher, one physics teacher, and one middle school science teacher. The experience level of participants in the control group also ranged from novice to veteran, with two of the participants being fairly new to the teaching profession (zero to five years’ teaching experience) and three of the participants possessing many years (10 to 25) of teaching experience. The full participation of the science department, with two-thirds of the department comprising the treatment group and one-third of the department comprising the control group, exceeded expectations for study enrollment and signified a successful enrollment process to the research study.

**Pre-Intervention: Data Collection**

Within one week of completing the informed consent process, the pre-intervention data collection began. The researcher performed classroom observations and
administered student and teacher surveys to collect quantitative, baseline data on the participants’ knowledge, pedagogical beliefs, and instructional practice. The classroom observations provided baseline data on the participants’ instructional practice and use of critical thinking instructional strategies. In addition, surveys administered to the teacher participants provided additional baseline data on the teachers’ pedagogical beliefs and knowledge of critical thinking development. Finally, surveys administered to students who were in the participants’ classes collected baseline data on the students’ perceptions of the teachers’ use of critical thinking instructional practices.

**Classroom observations.** The researcher contacted all 15 of the study participants to schedule initial classroom observations. The researcher conducted one 40-minute observation of each treatment and control group member over a three-week time period, commencing on September 13th and concluding on October 4th. The researcher used the RTOP instrument to determine the overall score for each of the lessons on their movement to reform based instruction. The total RTOP score, calculated by summating the scores from each of the three subscales (*Lesson Design and Implementation, Content,* and *Classroom Culture*), served to indicate the learner-centeredness of the lesson and the teachers’ use of reform-oriented teaching practices (Piburn et al., 2000).

Prior to conducting the observations, the researcher completed an online training session in order to increase rater reliability and ensure the accurate use of the RTOP instrument. The training session required the researcher to watch videos of and assess three exemplar science lessons. While observing each video lesson, the researcher recorded relevant notes on the observed instructional practices and used the RTOP instrument to score the lesson. After watching each exemplar lesson, as instructed by the
training website (Reformed Teaching Observation Protocol, 2007), the researcher compared her RTOP scores to those provided by an expert who previously rated the same lesson. The RTOP ratings provided by the expert rater included detailed explanations of the criteria used for assessing the lesson on each of the three subscales. The researcher then carefully scrutinized each of the Likert-scale questions within the RTOP subscales to determine the criteria the expert used to select the appropriate rating for each item. After observing each exemplar lesson, the researcher’s ratings of the lesson more closely reflected the expert’s ratings. After observing three exemplar lessons, the researcher was able to score the final exemplar lesson within seven points of the expert’s rating of the lesson. While the RTOP training website recommends that the trainee’s final score of the exemplar lesson be within five points of the expert rater’s score, the researcher aimed to enhance the accurate and reliable use of the instrument by consistently referring to the detailed RTOP scoring criteria recorded during the training session (Appendix C) when observing and rating the participants’ classroom lessons for the research study.

During the three-week initial observation period, in order to increase the validity of the observation findings, the researcher refrained from sharing with the participants the RTOP instrument or the criteria that would be used to rate the lessons to gather baseline data. However, after completing the pre-intervention observations, the researcher shared with the treatment group members the RTOP instrument for their use in self-evaluating and reflecting on future lessons.

During the three-week initial observation period, the researcher also scheduled one-on-one, 30-minute mentoring sessions with each of the treatment group participants, to be conducted after completing the teacher’s formal observation. In each 30-minute
mentoring session, the researcher discussed with the participant the components of the RTOP instrument and observation feedback from the lesson. The researcher also requested that the participant refrain from sharing any information about the RTOP instrument with other control and treatment group participants. To maintain fidelity of implementation, all classroom observations and mentoring sessions with the 10 treatment group participants were completed prior to the first professional development (PD) workshop, which took place on September 27th.

**Surveys.** During the three-week initial observation period, the researcher collected additional baseline data via a teacher critical thinking survey and the Course Evaluation Form (Foundation for Critical Thinking, 2007), both administered via Survey Monkey (Chapter 4, p. 127-132 for details about the instrumentation). The researcher distributed the links for the teacher pre-intervention survey and the Course Evaluation Form to the 15 study participants and to the students in the participants’ classes, respectively. The teacher survey collected demographic information and provided an indication of the participants’ existing knowledge of critical thinking and the extent to which their pedagogical beliefs support instructional practices that foster critical thinking development. The Course Evaluation Form, an evaluative tool used to assess classroom teaching practices, served as a pre-intervention indicator of the extent to which the students believe the classroom instruction supports their critical thinking development. Because the Course Evaluation Form was administered as part of a continuing process to solicit the students’ feedback on classroom teaching practices, parental permission was not needed to collect the student survey data for the study. All 15 of the study participants
completed the teacher survey, and 513 students (from middle and high school) completed the Course Evaluation Form.

**Intervention**

As outlined in the intervention design plan, the intervention required the treatment group participants to attend four professional development workshops and four small-group mentoring sessions with the researcher. In addition, the intervention required the treatment group participants to design and implement in their classes three discrete critical thinking assignments. In addition to the participants’ pre- and post-intervention RTOP ratings, the students’ scores on the critical thinking assignments served to indicate the participants’ effective application of critical thinking strategies learned in the professional development workshops. Finally, the intervention required the treatment group members to perform two peer observations using the RTOP instrument to provide their peers with feedback on the observed lessons.

**Professional Development Workshops.** As outlined in the intervention design, four professional development workshops were conducted across the duration of the intervention. However, while the proposal suggested the workshops be conducted over a three-month time period (beginning mid-September and concluding mid-December), due to unforeseen circumstances explained below, the PD workshops in reality were conducted over a five-month time period (beginning the end of September and concluding mid-February). Also, it should be noted that following the first PD workshop, the treatment group enrollment decreased from ten to eight members due to participant attrition. One member, a high school science teacher, resigned from his position at the school in mid-October and was therefore eliminated from the study. The second member,
also a high school science teacher, decided after the first PD workshop that the study requirements would be too overwhelming to complete within the designated timeframe and therefore withdrew from the study. Of note, this particular participant frequently expresses opposition to teacher professional development and tends to work in isolation; therefore, this participant’s decision to withdraw did not raise concerns over the intervention’s design. For the remainder of the study, eight science teachers comprised the treatment group, and five science teachers comprised the control group.

Several factors contributed to the need to extend the PD timeframe from three to five months. First, in order to maintain fidelity, the researcher needed to formally observe the participants’ classes and meet individually with each treatment group participant prior to conducting the first PD workshop. The process of scheduling the initial observations and one-on-one mentoring sessions at times mutually-convenient for the researcher and study participants proved to be more time-consuming than the researcher anticipated. Second, while the second PD workshop was held one month following the first PD workshop (as stated in the intervention design), the third workshop was re-scheduled for January 5th, over one month following the date for which this workshop was initially scheduled (November 29th).

The researcher decided to re-schedule the third PD workshop because three of the eight participants would be unable to attend on the November date due to unforeseen circumstances. Instead of conducting the workshop with only a 63% attendance rate and sacrificing fidelity (participant responsiveness), the researcher decided to reschedule the workshop for a later date when all members would be present. However, due to the impending Christmas holiday and numerous school traditions leading up the two-week
holiday break, the study participants agreed that re-scheduling the workshop for after the holiday break (first week of January) was the best strategy for ensuring 100% participation. Therefore, the third workshop was re-scheduled for January 5th. Yet, on this date, all school activities (including faculty meetings) were unexpectedly canceled in the afternoon due to a safety issue that required all students, faculty, and staff members to exit campus by 3:00 pm. Because the workshop was scheduled to begin at 3:30, this workshop once again needed to be re-scheduled. The study participants thus agreed to meet during the students’ exam week on January 18th (during a time they otherwise would not be required to be on campus). However, one participant was unable to attend at this time due to a prior obligation. Therefore, the researcher met separately with this participant to review the material covered in the 3rd PD workshop. All 8 of the study participants attended the final (4th) PD workshop on February 13th, less than one month following the third workshop.

Professional development workshop #1. The researcher prepared a presentation to guide the activities to be conducted and concepts to be explored during the first PD workshop. The workshop components aligned with the activities outlined in the intervention proposal. The presentation included slides with the following information: session objectives and agenda, activity overview (article discussion and reflection), critical thinking overview (what critical thinking is and why it is important), critical thinking components (from Paul & Elder, 2009), application of critical thinking in the science classroom (sample video lesson), and components of science assignments and lessons that foster critical thinking development.
In the implementation of the first PD workshop, the researcher adhered to all of the components as designed for this workshop. However, the time allotted to each component differed from the time frames suggested in the intervention proposal. While the researcher originally planned to provide the participants with 25 minutes at the end of the workshop to collaboratively design their first critical thinking assignment (due prior to the second PD workshop), the workshop activities required more time than anticipated. In particular, the additional time needed for the researcher to explain the upcoming study requirements (designing and grading critical thinking assignments, performing peer observations, using the RTOP instrument to provide peer feedback, and engaging in mentoring sessions) limited the amount of time that could be allotted to other tasks given the 90-minute timeframe. As a result, after completing the other activities (group discussions, video lessons, presentation by the researcher, etc.), only approximately 10 minutes remained for the participants to collaboratively discuss and design a critical thinking assignment. Consequently, participants were required to devote additional time outside of the workshop for designing a critical thinking assignment that would be administered in their classes.

At the end of the first workshop, the researcher assigned each participant to a partner in the treatment group for conducting peer observations. When possible, the participants were paired by discipline as follows: group 1 – two middle school science teachers, group 2 – two engineering teachers, group 3 – two chemistry teachers, group 4 – one physics and one environmental science teacher. The researcher requested that each participant perform one peer observation prior to the second PD workshop. The researcher also explained the protocol for conducting the peer observations; each
participant would use the RTOP instrument to score and provide feedback on the peer’s lesson and application of critical thinking instructional practices. The participant observer would provide the RTOP feedback to the peer during the small group mentoring session, to be held after the peer observation and prior to the second PD workshop.

**Professional development workshop #2.** The researcher prepared a PowerPoint presentation to guide the activities to be conducted and concepts to be explored during the second PD workshop. The workshop components aligned with the activities outlined in the intervention proposal. The PowerPoint presentation included slides with the following information: session agenda, a review of critical thinking components (from Paul & Elder, 2009), an introduction to the key features of critical thinking instruction, an overview of inquiry-based learning as a critical thinking instructional approach, three sample video lessons with accompanying reflection questions, and guidelines for a group activity in which participants, paired by discipline, collaboratively design an inquiry-based science lesson.

In the implementation of the second PD workshop, the researcher adhered to all of the components as designed for this workshop. However, the researcher opted to remove the first item outlined in the intervention proposal, which entailed providing time for the participants to collaboratively discuss and reflect on the first peer observation experience. Because the mentoring sessions (small group sessions that took place prior to the second PD workshop) provided time for the teachers to reflect on their lessons and discuss the RTOP feedback with their peers, the researcher concluded that additional time need not be devoted to this topic in the PD workshop. Eliminating this component of the workshop permitted additional time for the other PD components. However, as will be discussed in
the results, providing additional time for group collaboration may enhance the participants’ professional learning outcomes.

In addition, while the remaining PD activities aligned with those outlined in the intervention proposal, the time allotted to each component differed from the timeframes suggested in the proposal. While the researcher had planned to provide the participants with 40 minutes at the end of the workshop to collaboratively design an inquiry-based lesson to be implemented in their classes, the workshop activities required more time than anticipated. In particular, collaboratively discussing and reflecting on the concepts learned in the three sample video lessons required more time than the researcher anticipated during the intervention design phase. Consequently, only about 20 minutes, instead of the planned 40 minutes, were provided to participants for planning their inquiry-based lessons. As a result, some participants needed to devote additional time outside of the workshop for designing an inquiry-based lesson that would be implemented in their classes.

**Professional development workshop #3.** The researcher prepared a presentation to guide the activities to be conducted and concepts to be explored during the third PD workshop. The workshop components aligned with the activities outlined in the intervention design. The presentation included slides with the following information: session agenda, a review of critical thinking components (from Paul & Elder, 2009) and instruction (Abrami et al., 2015), a review of inquiry-based learning, an overview of problem-based learning as a critical thinking instructional approach, two sample video lessons with accompanying reflection questions, guidelines for a group activity in which
participants engaged in a problem-based learning activity, and instructions for working collaboratively to design a problem-based science lesson.

In the implementation of the third PD workshop, the researcher adhered to all of the components as designed for this session. However, while the intervention as planned entailed the use of PD workshop time for the collaborative discussion of the participants’ inquiry-based lessons, the participants instead discussed their lessons during the small-group mentoring sessions held prior to the third workshop. This adjustment in the workshop agenda permitted more time to be devoted to the other workshop activities. In particular, the effective completion of the activity in which participants worked in teams to solve an engineering problem required approximately 45 minutes instead of the 30 minutes originally allotted for this activity. Therefore, the decision to use mentoring session time in lieu of PD workshop time for collaboratively discussing the participants’ inquiry-based lessons permitted the workshop’s successful completion within the 90-minute timeframe, as planned. However, as will be discussed in the results, providing additional workshop time for group collaboration may enhance the participants’ professional learning outcomes.

**Professional development workshop #4.** The researcher prepared a presentation to guide the activities to be conducted and concepts to be explored during the fourth PD workshop. The workshop components aligned with the activities outlined in the intervention proposal. The presentation included slides with the following information: session agenda; a review of critical thinking components (from Paul & Elder, 2009), critical thinking instruction (Abrami et al., 2015), problem-based learning; guidelines for reflecting on and collaboratively discussing the critical thinking assignments developed
and implemented in the participants’ classes; and, instructions for working in teams to complete concept maps illustrating the critical thinking concepts and instructional strategies learned throughout the program.

In the implementation of the fourth PD workshop, the researcher adhered to all of the components as designed for this workshop. However, while the intervention as planned entailed the use of PD workshop time for the collaborative discussion of the participants’ problem-based lessons, the participants also discussed their lessons during the small-group mentoring sessions held prior to the fourth workshop. Therefore, the researcher decided to allot additional workshop time for group reflection and discussion on the critical thinking assignments that the participants implemented in their classes. The participants fully used the allotted collaboration time to reflect on the effectiveness of the critical thinking assignments and strategies for improving the assignments and their instructional approaches in the future.

After discussing their critical thinking assignments and the effectiveness of their instructional approaches, the participants worked in the same teams to create concept maps demonstrating their understanding of the concepts learned throughout the program. In particular, the researcher instructed each team to create a concept map illustrating the relationships between the following critical thinking concepts: the elements of thought and universal standards (Paul & Elder, 2009), the components of critical thinking instruction (Abrami et al., 2015), inquiry-based learning, problem-based learning, and the elements of critical thinking assignments (Paul & Elder, 2009). After completing their concepts maps, the teams shared with the group the concepts and relationships illustrated in their maps. Finally, while the researcher had planned to administer the final teacher
survey at the end of the workshop, the successful completion of the workshop activities required the entire 90-minute timeframe. Therefore, the researcher emailed the Survey Monkey link to the participants who completed the survey within one week following the workshop.

**Mentoring Sessions.** The researcher met with the treatment group participants in small groups at four time points across the duration of the intervention. The purpose of these 30-minute mentoring sessions was to provide an opportunity for the participants to reflect on their professional practice and target specific areas for improvement, and for the researcher to support the participants’ ongoing professional growth. For each mentoring session, with the exception of the first round, the researcher met together with the two participants who were paired with one another for conducting the peer observations. Therefore, the group members remained the same for each of these mentoring sessions. However, for the first round of mentoring sessions, the researcher met with each treatment group participant individually.

**Mentoring session #1.** The first round of mentoring sessions took place after the researcher performed the pre-intervention observations and before the first professional development workshop. For this round of mentoring sessions, the researcher met one-on-one with each treatment group participant. The purpose of the first mentoring session was for the researcher to provide the participant with the RTOP feedback from the pre-intervention classroom observation. At this session, the researcher also discussed with the participant the purpose of the RTOP instrument and its subscales, and the criteria used to rate the lesson components. The researcher then discussed the instrument’s usefulness in measuring the lesson’s effectiveness in supporting students’ critical thinking.
development. This first mentoring session provided an opportunity for the participants to become acquainted with the components of critical thinking instruction, to receive personalized feedback on their professional practice, and to identify pedagogical areas for improvement.

**Mentoring session #2.** The second round of mentoring sessions took place between the first and second professional development workshops, and after the first round of peer observations. The purpose of the second mentoring session was to provide an opportunity for the participants to provide their peers with feedback from the classroom observations, and for the researcher to provide additional guidance and support to foster the participants’ professional growth. During this mentoring session, the participants reviewed the purpose of the lesson that was observed, discussed the instructional strategies that were used to support the students’ critical thinking development, and reflected with their peer on the effectiveness of these strategies in enhancing students’ critical thinking outcomes. The participants referred to the RTOP instrument to identify lesson components that may be targeted for improvement. The participants then discussed strategies for improving their use of critical thinking instructional approaches in the future. Importantly, the participants also provided their peers with feedback and recommendations for improvement. This collaborative experience therefore encouraged the participants to reflect not only on the effectiveness of their own practice, but also on the effectiveness of their peers’ lesson and on strategies that might further enhance critical thinking development.

**Mentoring session #3.** The third round of mentoring sessions took place between the second and third professional development workshops. The purpose of the third
mentoring session was to provide an opportunity for the participants to reflect on their professional growth thus far, and for the researcher to provide additional feedback on the participants’ practice in order to support their continued adoption of critical thinking instructional approaches. In particular, in the second professional development workshop, the participants were asked to design, implement, and use the RTOP to reflect on the effectiveness of an inquiry-based lesson prior to the next professional development workshop. Therefore, the third mentoring session provided the participants with an opportunity to discuss with their peers and researcher evidence of the effectiveness of their inquiry-based lessons in promoting critical thinking development and to collaboratively brainstorm strategies for improving the lesson in the future. As in the first and second mentoring sessions, the participants specifically referred to the RTOP instrument items to identify lesson components that may be targeted for improvement. In addition, the participants considered critical thinking strategies learned in the first two professional development workshops that may be applied to further enhance student outcomes.

Mentoring session #4. The fourth round of mentoring sessions took place between the third and fourth professional development workshops, and after the second round of peer observations. The purpose of the fourth mentoring session was to provide an opportunity for the participants to provide their peers with feedback from the classroom observations, and for the researcher to provide additional guidance and support to foster the participants’ professional growth. In particular, in the third professional development workshop, the participants were asked to design, implement, and use the RTOP to reflect on the effectiveness of a problem-based lesson prior to the final
professional development workshop. Therefore, during this final mentoring session with their peer and the researcher, the participants reviewed the purpose of the problem-based lesson that was observed, discussed the instructional strategies that were used to support the students’ critical thinking development, and reflected on the effectiveness of the lesson in enhancing student outcomes. As in the previous mentoring sessions, the participants referred to the RTOP instrument to identify lesson components that may be targeted for improvement and applied knowledge gained from the professional development workshops to brainstorm strategies that may enhance the students’ critical thinking development. This collaborative experience therefore encouraged the participants to reflect not only on the effectiveness of their own practice, but also on the effectiveness of their peers’ lesson and on strategies that might further enhance students’ critical thinking outcomes.

**Critical Thinking Assignments.** At the first professional development workshop, the researcher requested that the treatment group members design and implement in their classes three assignments that promote students’ critical thinking development over the duration of the intervention. The purpose of this component of the intervention was to provide the teacher participants with a rubric for designing assignments that cultivate students’ critical thinking skills. The researcher provided the treatment group members with the Criteria for Critical Thinking Assignments (Foundation for Critical Thinking, 2015), a research-based rubric intended to facilitate the design of assignments that foster critical thinking development. The researcher also provided the treatment group members with the Critical Thinking Grid (Foundation for Critical Thinking, 2015), a research-based rubric to be used for scoring the students’ submitted work for the critical thinking
assignments. The Critical Thinking Grid assesses the extent to which the student, as indicated via the student’s work sample, effectively applies Paul and Elder’s (2009) elements of reason by: identifying the purpose and problem, representing appropriate points of view, providing relevant and accurate information, demonstrating an understanding of relevant concepts, identifying assumptions, making logical inferences, and identifying important implications and consequences (Foundation for Critical Thinking, 2015).

The researcher requested that the treatment group members design and implement a critical thinking assignment at each of the following time points: assignment one – between the first and second PD workshops; assignment two – between the second and third PD workshops; assignment three – between the third and fourth PD workshops. The purpose of staggering the assignment submissions in this manner was to observe any growth in the teachers’ ability to promote critical thinking development, as indicated by the students’ performance on the critical thinking assignments, over time. In addition, each of the control group members was asked to provide the researcher with student work samples from each of the assignments implemented at the time points indicated. However, the researcher did not provide the control group members with either the Criteria for Critical Thinking Assignment or the Critical Thinking Grid during the intervention. Therefore, the control group’s student work submissions would serve as an additional point of comparison for any observed effects over time.

All participants implemented critical thinking assignments in their classes following the recommended timeline and provided the researcher with student work samples for each assignment. The treatment group participants used the Critical Thinking
Grid, as requested by the researcher, to assess and score the student work samples. As discussed above, the scores on the student work samples are based on the extent to which students demonstrated the application of Paul and Elder’s (2009) elements of reason in completing the assignment. After the treatment group participants scored their students’ assignments using the Critical Thinking Grid, the researcher verified the participants’ accurate and reliable use of the rubric by scoring a sample of the submitted assignments from each participant and re-calibrating the scores to maintain consistency, as necessary. The researcher re-calibrated the scores if the alignment between the researcher’s scores and the teacher’s scores of the student work samples was less than 90 percent (i.e., if the teacher’s scores were not within two points of the researcher’s scores). In particular, if after scoring a sample of the submitted assignments the researcher found that the teacher’s assessment of each of the student work samples was not within two points of the researcher’s assessment of each of the student work samples, the researcher would re-score the set of assignments by carefully following the criteria on the Critical Thinking Grid. By doing so, the researcher helped to ensure the reliable use of the Critical Thinking Grid for assessing the students’ performance on assignments.

The control group participants also provided the researcher with student work samples for three assignments that were implemented in their classes at the designated time points. To assist in scoring the student work samples provided by the control group participants, the researcher recruited and trained an educator who is also experienced in scoring assessments for research purposes. For each assignment, the educator and researcher used the Critical Thinking Grid to collaboratively score the first student work sample. They carefully discussed the criteria that would be used to assign ratings of 1, 2,
3, or 4 for each item assessed on the rubric. Then, the researcher and educator worked separately to score the second student work sample for the same assignment. Next, the researcher and educator came back together to compare and discuss how they scored the second student work sample and re-calibrate their scoring methods, as needed. Finally, the remaining student work samples for the assignment were divided equally between and scored by the educator and researcher.

The educator and researcher repeated the aforementioned scoring protocol for each of the assignments provided by the control group participants and, in doing so, maintained an interrater reliability of 67%. The strength of this reliability score may be evaluated by comparing it to that achieved for a similar instrument. For example, Piburn et al. (2000) measured the inter-reliability for each of the RTOP subscales which, like the critical thinking assignments, also serve to assess the teachers’ application of critical thinking instructional practices. In particular, Piburn et al. (2000) deemed the 67% inter-rater reliability achieved for RTOP Subscale 3: Content – Procedural Knowledge to be relatively high for this type of instrument.

The researcher therefore had as per Piburn et al. (2000) a fairly high inter-rater reliability score given its similarity to that achieved for other instruments also used in measuring the application of critical thinking practices. Also, the scores for those assignments that were not within 100% agreement only differed by one to two points. Therefore, by following the scoring protocol discussed above, the researcher helped to ensure the accurate and reliable use of the Critical Thinking Grid for scoring the students’ assignments.
Findings

Research Question #1: To what extent did the intervention produce positive change in the teachers’ knowledge of instructional practices that foster students’ critical thinking?

Teacher Surveys: Pre- and Post-Intervention. The teacher surveys, administered pre- and post-intervention to both the treatment and control groups, served to indicate the extent to which the intervention produced positive change in the participants’ knowledge of critical thinking instructional practices. In particular, responses to the 5-point Likert-scale items in Part II: Knowledge of the survey indicated the respondents’ knowledge of pedagogical practices that cultivate critical thinking development. The Likert-scale responses ranged from 1 to 5, where a response of 1 indicated that the participant never applied knowledge of critical thinking practices, and a response of 5 indicated that the participant always applied knowledge of critical thinking practices. In addition, the participants’ knowledge of critical thinking was further assessed via qualitative analysis of their responses to an open-ended survey question on the attributes of a good critical thinker.

Pre-intervention survey results. According to basic descriptive analyses of Part II: Knowledge of the pre-intervention survey data, the mean response scores for the treatment (M = 3.70, SD = .291, N = 8) and control (M = 3.93, SD = .259, N = 5) groups suggest the respondents sometimes applied knowledge of critical thinking instructional practices prior to the intervention. In particular, the mean response scores suggest that the participants’ pedagogical knowledge (mediating variable) at the pre-intervention time-point sometimes supported their application of instructional approaches that cultivate critical thinking. Independent Samples T-tests revealed that no significant variation
existed between the mean Knowledge scores for the treatment and control groups at the pre-intervention time-point, \( t(11) = -1.391, p = .757 \).

Of note, while the treatment group’s pre-intervention mean response scores suggest relatively strong knowledge of critical thinking instructional practices prior to the intervention, the pre-intervention data collected from observations of the participants’ classroom instruction suggest otherwise. According to the pre-intervention mean observation score (42.63, RTOP level II), the treatment group’s application of teacher-centered instructional practices suggests that the participants’ pedagogical knowledge at that time-point did not translate to their effective use of instructional strategies that cultivate critical thinking skills in the classroom. These results will be further discussed under Research Question #3.

**Post-intervention survey results.** According to basic descriptive analyses of the post-intervention Knowledge survey data, the mean response scores for the treatment (\( M = 4.03, SD = .476, N = 8 \)) and control (\( M = 4.13, SD = .523, N = 5 \)) groups suggest the respondents often applied in their classes knowledge of critical thinking instructional practices following the intervention. In particular, the treatment group’s mean Knowledge score (\( M = 4.03, SD = .476 \)) suggests the participants’ pedagogical knowledge at post-intervention often supported their application of critical thinking instructional approaches following their participation in the intervention. However, while the treatment group’s post-intervention mean Knowledge score (\( M = 4.03, SD = .476 \)) increased relative to its pre-intervention mean Knowledge score (\( M = 3.70, SD = .291 \)), one-way ANOVA and post hoc Bonferroni analyses revealed that the difference in their Knowledge scores is not statistically significant (\( p = 0.706 \)). Therefore, the results suggest that the treatment group
participants experienced no significant change in their critical thinking pedagogical knowledge following participation in the intervention.

In addition, according to basic descriptive analyses of the post-intervention Knowledge survey data, the control group’s mean response score (M = 4.13, SD = .523, N = 5) suggests the respondents often applied knowledge of critical thinking instructional practices following completion of the intervention. While the control group’s post-intervention mean Knowledge score (M = 4.13, SD = .523, N = 5) is greater than the treatment group’s post-intervention mean Knowledge score (M = 4.03, SD = .476, N = 8), one-way ANOVA and post hoc Bonferroni analyses revealed that the difference in the groups’ post-intervention Knowledge scores is not statistically significant (p = 1.0). Furthermore, ANCOVA analyses [between-subjects factor: group (treatment, control); covariate: pre-intervention Knowledge survey] revealed no significant effects of group type on knowledge of critical thinking instructional practices, F(1, 10) = .195, p = .668, ηp² = .019.

However, while the quantitative survey results suggest that no significant change in the participants’ knowledge of critical thinking occurred over time, qualitative analysis of the open-ended survey responses suggests that, relative to the control group, the treatment group’s knowledge of critical thinking terminology improved after completion of the intervention. In both the pre- and post- intervention surveys, the treatment (n = 8) and control (n = 5) group participants recorded responses to the following open-ended question: “Complete the phrase: A good critical thinker is a person who…” The researcher used a priori coding (Saldana, 2016) to identify in the participants’ responses any words or phrases that reflected knowledge of critical thinking terminology learned in
the professional development workshops. Examples of a priori codes used in this primary coding process included: points of view, perspectives, purpose, question, problem, reason, logic, evidence, inference, theories, principles, assumptions, implications, analysis, evaluate. Therefore, the frequency of critical thinking codes identified in the responses served to indicate the participants’ knowledge of critical thinking terminology. The researcher then compared the frequency of codes identified in the treatment and control group’s responses at pretest and posttest. The coding process therefore revealed any change in the frequency of codes from pretest to posttest and, in turn, any change in the participants’ knowledge of critical thinking terminology following the intervention.

The researcher began the primary coding process by comparing the pre- and post-intervention survey responses recorded by the control group participants (n = 5). The small sample size permitted the researcher to apply manual coding and highlight any words or phrases that indicated knowledge of critical thinking terminology. The primary coding process revealed minimal change in the control group participants’ knowledge of critical thinking terminology from pre-intervention to post-intervention. Analyses of the critical thinking codes identified in the control group’s responses revealed an increase in frequency from four identified codes at pre-intervention to five identified codes at post-intervention (Table 5).

The researcher continued the primary coding process by comparing the pre- and post-intervention survey responses recorded by the treatment group participants (n = 8). Again, the small sample size permitted the researcher to apply manual coding and highlight any words or phrases that indicated knowledge of critical thinking terminology. In comparison to the control group findings, qualitative analyses of the treatment group’s
pre- and post-intervention responses revealed a more pronounced increase in the frequency with which critical thinking codes were identified. While analyses of the treatment group’s pre-intervention responses revealed nine critical thinking codes, analyses of the post-intervention responses revealed 13 critical thinking codes (Table 5). In addition, in the post-intervention survey, the treatment group participants’ more thorough explanations of the attributes of effective critical thinkers further supported a positive change in their critical thinking knowledge following participation in the intervention.
Of note, while only five critical thinking codes were identified in the treatment group’s open-ended responses at pre-intervention, eight critical thinking codes were identified in this group’s responses at post-intervention. The increase in the number of codes about the attributes of effective critical thinkers suggests an enhanced knowledge of critical thinking terminology among the treatment group participants. For example, in
the post-intervention survey, participant 8 demonstrated an enhanced knowledge of critical thinking terminology learned in the professional development workshops by stating that “A good critical thinker is a person who explores and expands their understanding using creative techniques.” The use of the terms “explore” and “expand” reflects the participants’ knowledge of terminology pertaining to the inquiry-based learning techniques learned during the second professional development workshop.

In addition, while not expressed by any of the participants in the pre-intervention survey, two treatment group participants in the post-intervention survey articulated the importance of viewing issues from multiple perspectives as a means of applying critical thinking skills. Participant 1 demonstrated knowledge of the importance of viewing issues from multiple perspectives by stating that “A good critical thinker is a person who critically assesses the information they receive to look at a problem from all angles and devise new ways of solving problems or evaluating concepts.” Participant 7 further expressed the importance of analyzing issues from multiple perspectives by stating that “A good critical thinker thinks from different viewpoints about a subject.” Participant 5 also demonstrated enhanced knowledge of critical thinking terminology by articulating that good critical thinkers “can formulate ideas, express their ideas, and help others to understand ideas.” Therefore, in response to the post-intervention open-ended survey question, the treatment group participants’ articulation of critical thinking terminology not previously expressed in the pre-intervention survey suggests enhanced knowledge of critical thinking terminology following the intervention.

In comparison, the observed change in the control group’s knowledge of critical thinking terminology following the intervention was less pronounced, with a slight
increase from three critical thinking codes identified at pre-intervention to four critical thinking codes identified at post-intervention. However, the new codes identified in the control group’s responses at post-intervention \((\text{analyze and evaluate})\) did not reflect terminology emphasized in the intervention. Conversely, several of the codes identified by the treatment group participants at post-intervention \((\text{critically assess, explore, formulate ideas, perspectives, and evidence})\) reflected specific terminology learned in the professional development workshops. Therefore, qualitative analyses of the pre- and post-intervention open-ended survey responses revealed the treatment group members’ increased use of critical thinking terminology following their participation in the professional development intervention.

In addition to the qualitative data collected via the open-ended survey question, qualitative data collected post-intervention from semi-structured interviews with the treatment group members provided further evidence that these participants gained important knowledge pertaining to critical thinking following their participation in the intervention. These results will be further discussed under Research Question #3.

**Research Question #2:** To what extent did the intervention produce positive change in the teachers’ pedagogical beliefs about critical thinking instructional practices?

**Teacher Surveys: Pre- and Post-Intervention.** The teacher surveys, administered pre- and post-intervention to both the treatment and control group participants, served to indicate the extent to which the intervention produced positive change in the participants’ pedagogical beliefs about critical thinking instructional practices. In particular, responses to the 5-point Likert-scale survey items in Part I: Beliefs indicated the respondents’ pedagogical beliefs about critical thinking
development. The Likert-scale responses ranged from 1 to 5, with a response of 1 indicating that the participant *strongly disagrees* with the statement about critical thinking pedagogy and a response of 5 indicating the participant *strong agrees* with the statement about critical thinking pedagogy.

**Pre-intervention survey results.** According to basic descriptive analyses of the pre-intervention *Beliefs* data, the mean response scores for the treatment (M = 4.29, SD = .282, N = 8) and control (M = 4.13, SD = .355, N = 5) groups suggest the respondents *somewhat agree* with statements that suggest their adherence to beliefs in favor of critical thinking instructional approaches. The mean response ratings of the participants’ pedagogical beliefs (*Part I* of survey) ranged from 2.88 (3 = *Neutral*) to 5.00 (5 = *Strongly Agree*) for the treatment group and 2.80 to 4.80 (4 = *Somewhat Agree*) for the control group. Independent Samples T-tests revealed that no significant variation existed between the mean *Beliefs* scores for the treatment and control groups at the pre-intervention time-point, t(11) = .939, p = .31.

**Post-intervention survey results.** According to basic descriptive analyses of the post-intervention *Beliefs* data, the treatment group’s mean response score (M = 4.36, SD = .319, N = 8) suggests the respondents *somewhat agree* with statements that suggest their adherence to beliefs in favor of critical thinking instructional approaches. However, while the treatment group’s post-intervention mean *Beliefs* score (M = 4.36, SD = .319, N = 8) increased relative to its pre-intervention mean *Beliefs* score (M = 4.29, SD = .282, N = 8), one-way ANOVA and post hoc Bonferroni analyses revealed that the difference in the treatment group’s *Beliefs* score is not statistically significant (p = 1.0). Furthermore, ANCOVA analyses [between-subjects factor: group (treatment, control); covariate: pre-
intervention Beliefs survey] revealed no significant effects of group type on pedagogical beliefs about critical thinking instructional practices, F(1, 10) = .575, p = .466, ηp² = .054. Therefore, the analyses suggest no significant change in the participants’ mean Beliefs score over time.

However, while the results suggest no significant change in the mean Beliefs score over time, multivariate tests of between-subjects effects revealed significant, positive changes in the treatment group’s Beliefs as indicated by Question 5 (M = 5.0, SD = .000) and Question 8 (M = 5.0, SD = .000) in Part I of the survey:

- Question 5: The multivariate tests revealed a significant, positive change in the treatment group’s belief regarding the need to increase the role of critical thinking into the curriculum, F(1, 11) = 16.127, p = .002, ηp² = .594.
- Question 8: The multivariate tests revealed a significant, positive change in the treatment group’s belief regarding the need for teachers to receive more training about how to teach critical thinking skills, F(1, 11) = 10.154, p = .009, ηp² = .480.

Therefore, after participating in the intervention, the treatment group experienced significant, positive changes to their pedagogical beliefs regarding the importance of critical thinking instruction and the need for teachers to receive training in critical thinking pedagogy. Conversely, the analyses revealed no significant change in the control group’s pedagogical beliefs following the intervention.

**Research Question #3:** How effective was the intervention in increasing the teachers’ adoption of critical thinking instructional practices?
Three quantitative data sources served to indicate the extent to which the intervention influenced the outcome variable: the teachers’ adoption of critical thinking instructional practices. These include the formal classroom observations completed pre- and post-intervention by the researcher, the critical thinking assignments implemented with students in the participants’ classes at three time-points during the intervention, and the course evaluations completed pre- and post-intervention by the participants’ students. In addition to the quantitative data sources, qualitative data collected from semi-structured interviews with the treatment group members following the intervention further revealed the extent to which the desired outcome was produced and the intervention components that most influenced any change in the outcome variable.

**Quantitative Results: Course Evaluations.** Both pre- and post-intervention, all treatment and control group participants administered, via Survey Monkey, the Course Evaluation Form (Foundation for Critical Thinking, 2007) to the students in their science classes. The course evaluation data served to gather the students’ perceptions regarding their teacher’s use of critical thinking instructional practices. For both the pre- and post-intervention course evaluations, the student respondents were categorized according to the participant group to which the student’s teacher belonged: *treatment* or *control*. The students responded to each item on the course evaluation form using a 5-point Likert scale, where “1” represented a *low score* and “5” represented a *high score* in reference to the instructional practice described for each item. Therefore, the higher the mean evaluation score, the more positive the student’s perception of the teacher’s use of critical thinking instructional practices.
According to T-test analyses of the mean course evaluation scores, the treatment group’s post-intervention mean course evaluation score (M = 3.91, SD = .755, N = 8) was not significantly different from the treatment group’s pre-intervention mean course evaluation score (M = 3.77, SD = .863, N = 8), t(422) = -1.633, p = .245. However, at both pre-test and post-test, the treatment group’s mean course evaluation scores fell closer to the high score than the low score on the instrument’s 5-point Likert scale. Similarly, at both pre-test and post-test, the control group’s mean course evaluation scores fell closer to the high score than the low score on the instrument’s 5-point Likert scale. However, T-test analyses revealed that the control group’s post-intervention mean course evaluation score (M = 3.93, SD = .977, N = 5) was significantly different from the control group’s pre-intervention mean course evaluation score (M = 3.82, SD = .759, N = 5), t(241) = -1.003, p = .030.

In addition, ANCOVA analyses were conducted to compare the post-intervention mean course evaluation scores in the treatment and control groups. The ANCOVA analyses [between-subjects factor: group (treatment, control); covariate: pre-intervention course evaluation] revealed no significant effects of group type on the course evaluation scores, F(1, 216) = 3.424, p = .066, ηp² = .016. Therefore, according to the univariate analyses of the course evaluation data, the teacher participants’ instructional practice remained unchanged following the teachers’ participation in the intervention. However, of note, at both pre-test and post-test the students tended to rate their teachers’ instruction as relatively high (closer to the high score than the low score) on the Course Evaluation Form.
Quantitative Results: Critical Thinking Assignments. At three time-points (1 = early-intervention, 2 = mid-intervention, and 3 = late-intervention), the researcher collected student work samples from assignments that the treatment group participants had designed and administered in their classes with the intention of promoting their students’ critical thinking development. At the same time-points, the researcher collected student work samples from assignments that the control group members had administered in their classes following business as usual. All of the student work samples were scored by the teacher participants and/or the researcher using the Critical Thinking Grid (Foundation for Critical Thinking, 2007). The Critical Thinking Grid (2007) data served to indicate the extent to which the assignments effectively promoted the students’ application of critical thinking skills.

According to basic descriptive analyses of the Critical Thinking Grid (2007) data, the treatment group’s (N = 132) total mean assignment score surpassed the control group’s (N = 67) total mean assignment score at each of the three time-points:

Table 6

<table>
<thead>
<tr>
<th>Time-Point</th>
<th>Group</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
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</thead>
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<tr>
<td>1</td>
<td>Treatment</td>
<td>17.46</td>
<td>8.101</td>
<td>132</td>
</tr>
<tr>
<td>1</td>
<td>Control</td>
<td>17.16</td>
<td>6.171</td>
<td>67</td>
</tr>
<tr>
<td>2</td>
<td>Treatment</td>
<td>20.54</td>
<td>8.971</td>
<td>132</td>
</tr>
<tr>
<td>2</td>
<td>Control</td>
<td>15.43</td>
<td>5.278</td>
<td>67</td>
</tr>
<tr>
<td>3</td>
<td>Treatment</td>
<td>17.4</td>
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<tr>
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<td>Control</td>
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<td>6.722</td>
<td>67</td>
</tr>
</tbody>
</table>

In particular, multivariate tests of between-subjects effects revealed a significant positive change in the treatment group’s mean assignment score (M = 20.54, SD = 8.971) relative to the control group’s mean assignment score (M = 15.43, SD = 5.278) at time-
point two, $F(1, 197) = 18.429$, $p = .000$. Furthermore, linear regression analyses of the treatment group’s assignment scores revealed a significant, positive association between time and mean critical thinking assignment scores, $\beta = .192$, $t(332) = 3.57$, $p = .000$. The time-point variable also explained a significant portion of variance in the critical thinking scores, $R^2 = .037$, $F(1, 332) = 12.73$, $p = .000$. Conversely, linear regression analyses of the control group’s assignment scores revealed no significant association between time-point and mean critical thinking scores, $\beta = .025$, $t(181) = .336$, $p = .737$; $R^2 = .001$, $F(1, 181) = .113$, $p = .737$. Therefore, as illustrated in Figure 4, the analyses suggest that the time over which participants received the intervention treatment significantly predicted students’ scores on the critical thinking assignments. Furthermore, as illustrated in Figure 5, the analyses revealed no significant difference in the control group’s critical thinking scores over time.

Figure 4

*Critical Thinking Assignment Scores in Treatment Group at Time-Points 1, 2 and 3*
Quantitative Results: Classroom Observations. Both pre- and post-intervention, the researcher used the RTOP instrument to collect quantitative data via classroom observations of all 13 participants. The RTOP scores from each classroom observation, conducted by the researcher, were placed into one of the following five categories (Holt et al., 2015): level I (15-30), level II (31-45), level III (46-60), level IV (61-75), or level V (76-100). The RTOP scores served to indicate the extent to which the participants adhered to instructional practices that foster the students’ critical thinking development. In particular, a transition from level I or II (both “teacher-centered” classrooms) to level III or higher (“learner-centered” classrooms) indicated the adoption of student-centered instructional practices that cultivate students’ critical thinking skills.

According to basic descriptive analyses of the RTOP data, the pre-intervention mean RTOP scores for both the treatment group (42.63, level II) and control group
(38.20, level II) suggest the participants’ adherence to teacher-centered instructional practices. However, one-way ANOVA and post hoc Bonferroni analyses revealed a significant positive change (p = .000) in the treatment group’s mean RTOP score (74.13, level IV) following participation in the intervention. The significant increase in the treatment group’s mean RTOP score from pre-intervention to post-intervention represents an effect size of 3.64 (Cohen’s d), which surpasses the magnitude needed (0.42) to demonstrate a significant treatment effect (Boston & Smith, 2009). In addition, ANOVA and post hoc Bonferroni analyses revealed significant variation (p = .001) between the post intervention treatment group’s (74.13, level IV) and control group’s (43.80, level II) mean RTOP scores. Finally, ANOVA and post hoc Bonferroni analyses of the control group’s mean RTOP scores revealed no significant variation (p = 1.00) between the pre-intervention (38.20, level II) and post-intervention (43.80, level II) scores.

Table 7

<table>
<thead>
<tr>
<th>Data Collection</th>
<th>Group</th>
<th>N</th>
<th>Mean (SD)</th>
<th>Effect Size (Cohen’s d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Intervention</td>
<td>Treatment</td>
<td>8</td>
<td>42.63 (9.86)</td>
<td></td>
</tr>
<tr>
<td>Post-Intervention</td>
<td>Treatment</td>
<td>8</td>
<td>74.13 (7.26)*</td>
<td>3.64</td>
</tr>
<tr>
<td>Pre-Intervention</td>
<td>Control</td>
<td>5</td>
<td>38.2 (9.96)</td>
<td></td>
</tr>
<tr>
<td>Post-Intervention</td>
<td>Control</td>
<td>5</td>
<td>43.8 (18.78)</td>
<td>0.37</td>
</tr>
</tbody>
</table>

*Significant increase from pre-intervention at p < .05

In addition, ANCOVA analyses were conducted to compare the post-intervention RTOP data from the treatment and control groups. The ANCOVA analyses [between-subjects factor: group (treatment, control); covariate: pre-intervention RTOP scores] revealed a significant, positive effect of group type on the mean RTOP score, F(1, 10) = 16.768, p = .002, ηp² = .626. Of note, the observed effect size (ηp² = .626), while lower than that revealed by the ANOVA analyses which do not take into account the pre-test,
still surpassed the magnitude needed (.42) to demonstrate a significant treatment effect (Boston & Smith, 2009). Therefore, according to univariate analyses of the RTOP data, the intervention produced a positive, significant effect on the teachers’ observed use of critical thinking instructional practices in their classroom context.

*Qualitative data from classroom observations.* Qualitative data collected by the researcher during the classroom observations further support the treatment group’s increased use of critical thinking instructional strategies following their participation in the intervention. In particular, during the post-intervention observations, five of the treatment group participants (Participants 1, 5, 6, 7 and 8) demonstrated enhanced application of inquiry-based learning techniques by placing the “explore” inquiry component prior to the “explain” component, as recommended by researchers (Marshall & Horton, 2011). For example, during the pre-intervention observation, Participant 1 demonstrated more traditional, teacher-centered instruction by explaining the concepts prior to encouraging student exploration of the concepts. According to the researcher’s notes recorded while observing Participant 1 at pre-intervention:

> The teacher began class by asking students about the lab investigation but was too quick to answer her own questions [instead of waiting for the students to answer them]. She explained to the students why proteins and lipids should be present in the cell membrane. Instead, she should ask the question and provide time for the students to construct responses. When a student did respond to a question, the teacher was too quick to confirm the response. The teacher needs to ask more questions to push the students’ thinking.
However, during the post-intervention observation, Participant 1 demonstrated a transition to student-centered, inquiry-based instruction by encouraging the students to explore the concepts prior to explaining them. According to the researcher’s notes recorded while observing Participant 1 at post-intervention:

The teacher begins by asking for a student volunteer to remind the class of the purpose of the lab investigation that they performed during the previous class. To review the concepts reviewed in the lab [performed in the previous class], the teacher asks the students to explain the methods of pollination. When nobody answers, the teacher asks the students to talk with a partner about the methods of pollination. Students are then able to offer a response. The students then break into pairs to start the next lab investigation – a flower dissection. The students explore the anatomy of the flower. By the end of class, the students will need to predict [based on the anatomy of the flower] the method of pollination used to pollinate each flower. The teacher gives the students a handout with questions that help them to think through what they know or need to know to figure out the method of pollination. The guided questions help the students to devise theories about the flower’s method of pollination.

During the post-intervention lesson observed by the researcher, Participant 1 encouraged the students’ application of critical thinking skills by asking them to make predictions and devise theories about the flower’s method of pollination, and by placing the “explore” before the “explain” inquiry component.

Similarly, Participant 7 demonstrated a transition from traditional to critical thinking instruction by effectively implementing inquiry-based learning during the post-
intervention lesson observed by the researcher. According to the researcher’s notes recorded while observing Participant 7 at pre-intervention:

The teacher begins class by displaying the objectives and asking for the definition of a theory. The teacher writes the response on the board. She then asks for the definition of a law and writes the definition on the board. The teacher explains the definition of elements and compounds. She displays the chemical symbols and tells the students that the first letter is always capital and the second letter is always lower case. Instead, the teacher could ask the students to describe what they observe about the symbols and what they all have in common.

While Participant 7 adhered to teacher-centered instruction during the pre-intervention observation, Participant 7 demonstrated a transition to student-centered, inquiry-based instruction during the post-intervention observation. According to the researcher’s notes recorded while observing Participant 7 at post-intervention:

The teacher introduces a short lab activity which will serve to demonstrate the concept of energy change. She asks the students to work in groups to answer questions A and B on the lab handout. The questions are thinking questions about heat transfer. The teacher then asks the students to predict what will happen in the experiment and to write down their predictions (will the reaction release or absorb energy?)… The students work in groups to perform the procedures. They perform the experiment to test if the reaction between baking soda and vinegar will release or absorb energy based on the observed temperature change and compared to the control. The teacher circulates to each group to ask the students to describe their findings and to explain how they came to their conclusions.
In contrast to the pre-intervention lesson, Participant 7’s effective use of inquiry-based learning during the post-intervention lesson suggests her transition to critical thinking instruction. In particular, by placing the “explore” before the “explain” inquiry component in the post-intervention lesson, Participant 7 more effectively supported the students’ critical thinking development.

In addition, during the post-intervention observations, three of the treatment group participants (Participants 2, 3, and 4) demonstrated a transition to critical thinking instruction by replacing their traditional, teacher-centered practices with student-centered, problem-based learning approaches. For example, at pre-intervention, Participant 2 implemented traditional instructional approaches to promote the students’ understanding of mass and volume. According to the researcher’s notes recorded while observing Participant 2 at pre-intervention:

The teacher begins class by instructing the students to silently read the objectives and vocabulary stated in their workbook… As the teacher presents the information on mass, the students follow along by underlining and highlighting the corresponding content in their workbooks… The teacher explains the relationship between weight, gravity, and the size of a planet. The teacher explains to the students that mass stays the same while the weight changes on different planets.

While Participant 2 applied more traditional, teacher-centered approaches during the pre-intervention observation, her effective use of problem-based learning during the post-intervention observation demonstrated her transition to critical thinking instruction.
following the intervention. According to the researcher’s notes recorded while observing Participant 2 at post-intervention:

The teacher gives the students a problem that they must solve in groups. They are provided with materials for solving the problem. She asks the students to identify the independent and dependent variables. She hands out a paper on which the students are instructed to write the problem statement, hypothesis, data, and answers to the analysis questions. As a group, the students collaborate to determine how they will solve the problem: How many times will you reduce force by using rolling friction instead of sliding friction? The students use ramps, string, cars with wheels, weights, lab quest devices, etc. to design their experiments. The students seem confident in seeking out materials and designing their experiments to test their hypotheses. All of the students are actively engaged in designing their experiments. The teacher checks in with each group to discuss their plans and facilitate their learning.

Overall, the treatment group members’ post-intervention lessons demonstrated their increased adoption of critical thinking instruction following their participation in the intervention. In particular, as noted during the post-intervention observations, the participants’ application of inquiry- or problem-based learning approaches indicated their adoption of instructional practices that more effectively cultivate their students’ critical thinking skills.

**Quantitative Results: Process Evaluation.** Upon completion of the intervention, the treatment group participants (N = 8) responded to a set of 16 Likert-scale survey questions (Appendix C) that required them to rate on a scale of 1 to 4 (1 = no influence, 2
= minor influence, 3 = moderate influence, and 4 = strong influence) the extent to which
the different intervention components positively influenced their critical thinking
instructional practice. According to basic descriptive analyses of the survey data, the
following intervention components, with mean scores ranging from 3.57 to 3.88, had a
moderate influence to strong influence on the participants’ ability to teach in a manner
that cultivates their students’ critical thinking skills: Professional development workshops
(Q1; mean score = 3.88); small-group mentoring sessions (Q2; mean score = 3.63); in the
PD workshops, collaborative discussions on instructional practice (Q7; mean score =
3.63); in the PD workshops, learning about the components of critical thinking (Q8; mean
score = 3.75); in the PD workshops, learning about the features of critical thinking
lessons (Q9; mean score = 3.63); in the PD workshops, learning about the different types
of critical thinking instructional approaches (Q10; mean score = 3.74); in the PD
workshops, watching videos that model critical thinking instructional approaches (Q11;
mean score = 3.57).

According to basic descriptive analyses, the following intervention components,
with mean scores ranging from 3.00 to 3.25, had a moderate influence on the
participants’ ability to teach in a manner that cultivates their students’ critical thinking
skills: Performing observations of peers (Q3; mean score = 3.00); individually reflecting
on the RTOP feedback (Q5; mean score = 3.00); collectively reflecting on the RTOP
feedback with the researcher and/or peers (Q6; mean score = 3.13); using the Criteria for
Critical Thinking Assignments (Foundation for Critical Thinking, 2007) worksheet to
design and implement class assignments (Q12; mean score = 3.13); using the Criteria for
Critical Thinking Grid (Foundation for Critical Thinking, 2007) to evaluate the students’
work on the class assignments (Q13; mean score = 3.13); in the PD workshops, comparing student work samples and/or lessons to those of colleagues during discussions regarding the effectiveness of instructional approaches (Q14; mean score = 3.25). The post-intervention interviews with the treatment group members (discussed under Qualitative Results) provided additional insight into the most and least influential components of the intervention.

Table 8

Influence of Intervention Components on Participants’ Instructional Practice, from Highest Influence to Lowest (1 = No Influence; 4 = Strong Influence)

<table>
<thead>
<tr>
<th>Mean Score</th>
<th>Intervention Component</th>
<th>Survey Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.88</td>
<td>Professional Development Workshops</td>
<td>1</td>
</tr>
<tr>
<td>3.75</td>
<td>Learning about CT components (in PD workshops)</td>
<td>8</td>
</tr>
<tr>
<td>3.74</td>
<td>Learning about CT instructional approaches (in PD workshops)</td>
<td>10</td>
</tr>
<tr>
<td>3.63</td>
<td>Small-group mentoring sessions</td>
<td>3</td>
</tr>
<tr>
<td>3.63</td>
<td>Collaborative discussions on instructional practice</td>
<td>7</td>
</tr>
<tr>
<td>3.63</td>
<td>Learning about features of CT lessons (in PD workshops)</td>
<td>9</td>
</tr>
<tr>
<td>3.57</td>
<td>Watching videos that model CT instruction (in PD workshops)</td>
<td>11</td>
</tr>
<tr>
<td>3.25</td>
<td>Comparing student work samples/lessons to those of colleagues</td>
<td>14</td>
</tr>
<tr>
<td>3.13</td>
<td>Collectively reflecting on RTOP feedback with peers</td>
<td>6</td>
</tr>
<tr>
<td>3.13</td>
<td>Using the Criteria for CT Assignments tool</td>
<td>12</td>
</tr>
<tr>
<td>3.13</td>
<td>Using the CT Grid to evaluate students' work on assignments</td>
<td>13</td>
</tr>
<tr>
<td>3.00</td>
<td>Performing peer observations</td>
<td>4</td>
</tr>
<tr>
<td>3.00</td>
<td>Individually reflecting on RTOP feedback</td>
<td>5</td>
</tr>
</tbody>
</table>

As discussed further in the Qualitative Results below, the post-intervention interviews with the treatment group members provided a deeper understanding of why the reported intervention components (Table 8) influenced the participants’ professional practice. Qualitative analyses of the interview data led to the emergence of themes, the
most prominent of which was support. As explained in the interview findings, the participants expressed appreciation for the level of support provided via the ongoing, collaborative professional development workshops and mentoring sessions. In addition, the participants positively regarded learning about specific critical thinking strategies in the professional development workshops. In particular, they positively acknowledged the amount of support they received for learning how to effectively adapt and apply the promoted strategies to their specific classroom context. The videos of exemplar lessons and tools such as the Critical Thinking Grid and RTOP instrument all supported the participants’ ability to effectively apply the learned concepts to their subject areas. Finally, collaboratively reflecting on their application of the learned critical thinking strategies, while using the RTOP or Critical Thinking Grid as a guide, further supported the participants’ professional growth and adoption of the promoted instructional practices.

In addition to assessing the influence of specific intervention components on the participants’ instructional practice, survey questions 15 and 16 (Appendix C) served to evaluate the level of program differentiation by inquiring about the extent to which the participants shared program information with control group members during the intervention. According to the survey results, which required the respondents to rank their responses from 1 to 5 (1 = always, 2 = sometimes, 3 = rarely, 4 = never), six respondents never shared information from either the professional development workshops or small-group mentoring sessions with members of the control group, one respondent rarely shared information from the workshops and mentoring sessions, and one respondent sometimes shared information from the workshops and mentoring sessions. Therefore,
while most program information remained confidential and was discussed only between treatment group members, some contamination may have occurred as a result of two treatment group members sharing program information with the control group. The control group contamination may, consequentially, dilute the strength of the observed treatment effects (Shadish et al., 2002).

**Qualitative Results: Interviews.** Following the intervention, the researcher conducted one-on-one, semi-structured interviews with each of the treatment group participants. The interviews served to (1) indicate the extent to which the intervention positively influenced the participants’ use of critical thinking instructional practices and (2) to provide further insight into the intervention components that most contributed to any observed change in the participants’ instructional practice.

Within two weeks after completing the intervention, the researcher met individually with each of the eight treatment group participants. Each interview lasted 20 to 30 minutes. During the semi-structured interviews, the researcher asked each participant six, pre-constructed questions to develop a deeper understanding of the intervention’s impact on the participant’s practice. The researcher asked additional, follow-up questions when further clarification was needed. The researcher used Microsoft Word to transcribe the participants’ responses.

After completing the interviews, the researcher engaged in the pre-coding process by carefully reading through the transcripts and highlighting any statements or passages that pertained to the research questions and provided further insight into the intervention’s impact. Relevant passages contributed by each participant were then transferred to an Excel spreadsheet and organized by theme. Using the spreadsheet, the
researcher identified patterns in the data, organized similar passages into groups, and assigned primary, descriptive codes that best captured the participants’ sentiments (Saldana, 2016). Upon further analysis of the primary codes, the primary investigator identified additional patterns and created secondary codes to further consolidate the data into categories (Saldana, 2016).

The categorization of data during the primary and secondary coding cycles led to the emergence of themes that characterized the findings (Saldana, 2016). The emergent themes include: time, support, and focused. In particular, the theme of time emerged as a result of the participants positively acknowledging the on-going nature of the intervention and the ample provision of time to practice and reflect on new strategies. The theme of support emerged as a result of the participants positively acknowledging the support they received via peer collaboration, observation feedback, mentoring, and the workshop components that fostered the transition from theory to practice. The theme of focused emerged as a result of the participants positively acknowledging the intentional, relevant, and goal-oriented nature of the intervention as a whole. In addition, in reference to the study’s research questions, themes emerged that indicated the respondents’ positive changes in knowledge (RQ 1), pedagogical beliefs (RQ 2), and instructional practice (RQ 3) as a result of participating in the intervention. The emergent themes, their corresponding codes, and the frequency of each code are illustrated in Table 9.
Table 9

Post-Intervention Interview with Treatment Group Participants: Emergent Themes

<table>
<thead>
<tr>
<th>Theme</th>
<th>Code</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Ongoing</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Practice</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Reflection</td>
<td>7</td>
</tr>
<tr>
<td>Support</td>
<td>Feedback</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Collaboration</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Application</td>
<td>12</td>
</tr>
<tr>
<td>Focused</td>
<td>Goal-oriented</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Relevant</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Intentional</td>
<td>4</td>
</tr>
<tr>
<td>Change in Knowledge (RQ 1)</td>
<td>CT development</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>4 E's</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IBL/PBL</td>
<td>10</td>
</tr>
<tr>
<td>Change in Beliefs (RQ 2)</td>
<td>Benefits</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Enjoyable</td>
<td>7</td>
</tr>
<tr>
<td>Change in Practice (RQ 3)</td>
<td>CT integration</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>IBL/PBL</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Student-centered</td>
<td>6</td>
</tr>
</tbody>
</table>

**Time.** The intervention was designed to include research-based professional development features that promote change in teachers’ practice. Among other features, research suggests that professional development programs that are ongoing and provide ample time to practice learned strategies are more likely to produce the desired change in teachers’ practice (Desimone et al., 2002). During the interview, many participants acknowledged the ongoing nature of the intervention and the benefits of using the professional development time to practice and reflect on the learned instructional strategies. When asked to compare the professional development program to others she had experienced, Participant 3 expressed that “this program was ongoing – each session built on itself – unlike other professional development experiences where it’s a different topic each time.” According to Participant 1:
The program was extended over many sessions, which was effective because it was one thing revisited. So many times with [other] professional development experiences we try to do a different thing each time and nothing ever gets practiced. We’ve started so many things that we’ve never followed through on.

There was much more follow-through with this one.

Similarly, Participant 6 recalled that, when compared to other professional development experiences, “there was a lot more time [in this program] to think about lesson plans, to plan them, and to get feedback from other teachers about what works for them.” The same participant went on to express that “having time set aside to explore lesson designing [before implementation] and discuss how effective they were [after implementation] was helpful. Lesson planning and reflection is time that is not usually set aside.” Overall, the ongoing nature of the program and the time it permitted for practice and reflection (in both the professional development workshops and small-group mentoring sessions) were referenced multiple times (16 total) by participants during the interviews.

**Support.** In addition to providing the participants ample time for practice and reflection, the intervention was designed to provide ample support structures that would foster the participants’ adoption of the promoted critical thinking instructional practices. During the interviews, the participants acknowledged the support they received from various intervention components, especially the professional development workshops and mentoring sessions during which they engaged in collaborative discussions with and received constructive feedback from peers and the researcher. According to Participant 6, “Time spent with peers – in professional development or in the mentoring sessions or
observing lessons – was most helpful because it gave more dedicated time to talk to other teachers and to give and get feedback on lessons.” In reference to the collaborative discussions that occurred in the professional development workshops, Participant 4 expressed that “it was great to bounce ideas off of each other.”

In addition to providing support in the form of peer collaboration and feedback, the professional development workshops included features that supported the participants’ application of the learned practices to their classroom context. Several participants acknowledged features, such as learning about specific strategies and viewing videos of exemplar lessons, which facilitated their effective use of the learned strategies. According to Participant 4:

Sometimes in professional development you play around with technology, but if you don’t learn how to apply it to your classes, it’s sort of a waste. But with our professional development, I learned specific ways to apply [the learned strategies] in my classes.

Furthermore, in regards to the exemplar lessons that were viewed in the professional development workshops, Participant 4 explained that “the videos were super awesome. I liked seeing that this is how they actually do this strategy.” In reference to the problem-based learning (PBL) approaches that were learned in the third professional development workshop, Participant 3 explained that:

I learned about PBL as part of my graduate coursework, but I never learned how to do it for the high school level. Now I have a much better idea of how to design a PBL lesson for high school students.
Similarly, Participant 5 expressed that “having to implement [inquiry-based or PBL approaches] as part of the program was helpful. Watching the videos was ok, but it was more useful having the opportunity to practice the strategies.” Finally, according to Participant 1, the “combination of presentations that provide concrete ways of applying the critical thinking techniques with having time to apply those techniques” was most helpful. This participant went on to express that “I understand in theory how to get the kids thinking, but before the workshops I was not as clear on how to apply [critical thinking strategies] in my classroom context.”

In addition to acknowledging the support provided via the professional development workshops, Participant 2 asserted that the mentoring sessions had the greatest impact on her practice because “good ideas came out of these.” Similarly, Participant 1 expressed that:

The group mentoring sessions were helpful. It was helpful to have [the researcher’s] input in addition to input from my peer. Hearing [the researcher’s] feedback to my peer as well as to me was helpful and I could apply the feedback [provided to both my peer and me] to my own lessons.

In general, the participants referenced multiple times (27 total) that the intervention, in particular the professional development workshops and the mentoring sessions, supported their learning and application of critical thinking instructional practices.

**Focused.** In addition to providing ample time and support, the intervention was structured to focus on specific critical thinking components and instructional strategies that the participants could easily adapt to their specific science subject areas. During the interviews, the participants positively acknowledged the intervention’s intentional, goal-
oriented, and science-specific structure. According to Participant 1, in comparison to other professional development experiences, this program was “distinctly more focused and more intentionally-undertaken as opposed to a general, non-targeted focus. It was a lot more practical. It’s like, here’s the topic, here’s the information and ideas to apply, now try it on your own.” Similarly, in comparison to other professional learning experiences, Participant 8 expressed that “[This program] was focused on critical thinking, so it forced you to think about your lesson plan and what it means for the students who need to be at the center [of learning]. It was phenomenal in that respect.” Participant 7 recognized that “[the intervention] wasn’t trying to change the climate of the whole school, but was focused on better teaching of science, [and was applicable to our] subject area and subject curriculum.” Finally, Participant 4 shared that:

I am a person who likes to have a goal or objective, and I don’t respond well when [the professional development involves] just playing around with technology [without having a defined goal to work towards]. I really appreciated that [this professional development program] was structured and I felt I got something out of it. It was helpful to have a goal to work towards.

In general, the respondents expressed that the focused and relevant nature of the intervention set it apart from other professional learning experiences in which they have previously participated.

**Change in Knowledge (RQ 1):** In addition to the themes of time, support, and focused, the interview data support the first research question by revealing a positive change in the participants’ knowledge of critical thinking instruction as a result of participating in the intervention. In particular, the interview responses revealed a positive
change in the participants’ knowledge of critical thinking development, specific critical thinking instructional approaches (inquiry-based and problem-based learning), and the importance of encouraging student exploration prior to the explanation of concepts (4 E’s). In regard to her enhanced knowledge and use of inquiry-based approaches, Participant 2 asserted that:

[the students] might not remember all the facts, but they’ll get the skills. The [IBL approach] helps them to take risks; they learn it’s ok to try. We don’t need to give them all the facts; they can look them up. If we take too much time for direct instruction, we’re losing hands-on or experimental time.

As a result of her engagement in the intervention, Participant 3 improved her knowledge of problem-based learning, as indicated by her sharing that:

I learned about [PBL] as part of my graduate coursework, but I never learned how to do it for the high school level. I now have a much better idea of how to design a problem-based lesson for high school students.

In reference to her enhanced knowledge of the importance of student exploration prior to explanation (4 E’s), Participant 6 expressed that this approach was the “easiest to implement” and “doesn’t require much time but can have a big impact on the lesson design and what students take away from the lesson.” She went on to share that, in her classes, she “focus[es] first on exploring concepts. Students come to an understanding themselves instead of saying ‘here’s what we’re doing, here’s what we’re going to explore.’” As indicated by the participants’ numerous comments regarding their enhanced understanding of the learned instructional approaches, the intervention produced a positive change in their pedagogical knowledge of critical thinking practices.
**Change in Beliefs (RQ 2):** The interview data also support the second research question by revealing a positive change in the participants’ pedagogical beliefs as a result of participating in the intervention. In particular, the interview responses suggest that the intervention positively influenced the participants’ beliefs about the benefits of integrating the learned critical thinking strategies and the joy experienced from teaching and learning in a student-centered environment. Participant 2 expressed the benefits of problem-based learning by referencing her recent experiences with implementing this novel approach in her classes and asserting that:

> it’s not a failure if [the students] don’t figure it out. We could have shown them how to [solve the problem] – that’s how it’s been done in previous years. But it was ok to fail. It’s amazing how many neurons were firing [for the students] to do that task; they were still learning even if they didn’t solve the challenge.

Similarly, in reference to the professional development program and the learned instructional approaches, Participant 4 shared:

> I wish we had more opportunities like this. As a new teacher, I don’t think about things like critical thinking, and when you try them, and they’re so great, you want to know what else is out there that I should be incorporating. I think the students remember [concepts] better when using these strategies. They have fun, they remember it, and they do better on quizzes, all because they’re absorbing information differently.

In comparing the intervention to previous professional development experiences, Participant 6 claimed that it was “easier to see the benefits [with the intervention]. Sometimes we learn something but don’t really see the benefits. But in this [program], it
was easy to see from the beginning the benefits.” She went on to express that “students might get frustrated because [inquiry-based approaches] are more challenging, but they get more out of it. They seem to understand things better.” In general, the positive change observed in the participants’ pedagogical beliefs regarding critical thinking instruction promotes their adoption of the learned instructional strategies.

**Change in Practice (RQ 3).** The interview data also support the third research question by revealing a positive change in the participants’ use of critical thinking instructional practices. In particular, the interview responses suggest that the intervention positively influenced the participants’ integration of critical thinking strategies, application of inquiry- and problem-based learning approaches, and overall transition to student-centered learning practices. In comparing the intervention to other professional learning experiences, Participant 2 shared that the intervention “sits on top because we are using so much of what we learned from it. We altered our style of teaching.” She went on to explain that:

We are doing things so drastically different now. [The intervention] had a huge impact. I’ve learned to let go of traditional teaching. [Inquiry-based learning] does take longer, but it’s more fun for [the students]. We are doing a lot more hands-on activities in class.

Participant 3 shared that, as a result of participating in the professional development program, “I have changed the way I do my questioning. I include a lot more compare and contrast questions. I also focus less on explaining and more on exploring.” Participant 4 shared that, after participating in the program, she implemented a problem-based approach in her environmental science classes to explore the effects of oil spills and over-
fishing. Participant 5 expressed the benefits of being able to adapt the inquiry-based approach to her middle school science classes. She explained that she is:

implementing the strategies on a smaller scale by switching the order in which I do things. Like, doing demonstrations before instruction, or having [the students] come up with the laws before teaching them. They did this by analyzing the data first before I presented the information.

According to Participant 6, the intervention “had a relatively large impact on how I’m looking at each lesson and planning each lesson. That’s been very beneficial.” Participant 7 shared that:

I’ll be more intentional about including some critical thinking questions over the year. I feel especially with sophomores that [critical thinking] skills need to be developed, and they need to be developed over the whole year. So, over the next couple of years, I’ll be working on bringing in some of these broader [critical thinking] questions so that the students will have experience with them.

Overall, the interview data provided important insights and in-depth information to further support the intervention’s positive influence on the participants’ knowledge, pedagogical beliefs, and instructional practice.

**Qualitative Results: Program Evaluation.** In addition to revealing emergent themes, qualitative analyses of the interview data elucidated the intervention components that, according to the perceptions of the respondents, most and least contributed to any observed change in the participants’ professional practice. During the interviews, the researcher asked the participants to identify the intervention components that most influenced any change in their practice, and those components that least influenced their
practice. Using a priori coding, each intervention component indicated by participants represented a code for the corresponding category (most influential or least influential). The researcher calculated the frequency of the codes and thus the strength of the different components in influencing change in the participants’ practice.

In addition, during the interviews, the researcher asked the participants to provide suggestions for improving the intervention in the future. Qualitative analyses of the interview data for this question revealed emergent codes that characterized the subjects’ suggestions for improving the program. Again, first and second cycle coding cycles (Saldana, 2016) were used to create categories from which common themes emerged. The categories, their corresponding codes, and the frequency of each code are illustrated in Table 10.

Table 10

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most influential</td>
<td>PD workshops (group collaboration)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Practice</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>RTOP</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Peer observations</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Videos</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mentoring sessions</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>CT Grid</td>
<td>2</td>
</tr>
<tr>
<td>Least influential</td>
<td>RTOP</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>CT Grid</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>2</td>
</tr>
<tr>
<td>Change</td>
<td>Timing of workshops</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>More collaboration</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Training: RTOP</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Training: CT Grid</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Individual support</td>
<td>2</td>
</tr>
</tbody>
</table>
**Most influential.** The participants identified numerous intervention components that they perceived as being influential in changing their professional practice. Some participants identified more than one component as having the greatest impact on their practice. First, all eight respondents asserted that participation in the professional development workshops most positively influenced their practice. In particular, the participants praised the ample time allotted during the workshops and mentoring sessions for group collaboration. Second, eight participants stated that the provision of time for practicing the learned strategies during and between workshops positively influenced their professional practice. Third, five participants selected the RTOP instrument as an intervention component that positively influenced their practice. In particular, some participants found the RTOP instrument to be useful in reflecting on and improving the effectiveness of their lessons. For example, Participant 8 identified the RTOP as the most influential intervention component and asserted that “the RTOP was extremely useful. It was good that it was brought in early [in the intervention]. We used [the RTOP] to evaluate our engineering lessons.”

Fourth, five participants identified peer observations as being a beneficial component of the intervention. The participants seemed to greatly value receiving peer feedback on their classroom practice. Fifth, five participants claimed that the videos of exemplar lessons facilitated their ability to apply the learned strategies in their classroom context. Sixth, four participants identified the small-group mentoring sessions as an intervention component that positively influenced their practice. Again, appreciation for the opportunities to collaborate with and receive feedback from peers, both in the professional development workshops and the mentoring sessions, was an overriding
theme that emerged from the interviews. Lastly, two participants claimed that designing critical thinking assignments using the Critical Thinking Grid positively influenced their professional practice. For example, Participant 6 asserted that “the Critical Thinking Grid was helpful in designing lessons.” Similarly, Participant 2 expressed that “the Critical Thinking Grid was helpful. I liked it better than the RTOP. [The Critical Thinking Grid] was especially helpful for backwards planning because I tried to adjust the assignments to the Grid in order to better cultivate [critical thinking] lessons.”

The most influential program components tend to reflect the themes that emerged from the interview data. In particular, time for group collaboration and reflection; support provided via the professional development workshops, peer observations, and mentoring sessions; and, resources (RTOP, CT Grid, video lessons) that facilitated the application of the learned strategies in the classroom context, all positively influenced the participants’ practice.

**Least influential.** The participants also identified intervention components that they perceived to be least influential in changing their professional practice. Some participants identified more than one component as having the least impact on their practice. First, three participants identified the use of the RTOP instrument as having the least impact on their practice. While five of the participants expressed that they appreciated receiving the RTOP feedback on their classroom practice, the three participants who identified the RTOP as being the least influential believed that additional training in the accurate use of the instrument would enhance its effectiveness as an evaluation tool. Participant 5 explained that “I didn’t really master [the RTOP]. I felt like it was verbose. I would need more instruction [on how to effectively use the
RTOP] in order to get more out of it.” Similarly, Participant 1 expressed that “I struggled with the RTOP and how best to apply it and use it as an effective evaluative tool.”

Second, two participants claimed that using the Critical Thinking Grid (Foundation for Critical Thinking, 2007) to design and score student assignments minimally impacted their practice. As with the RTOP instrument, these participants felt that additional training in the accurate use of the Critical Thinking Grid would improve its effectiveness as a critical thinking assessment tool. According to Participant 4, “the Critical Thinking Grid was difficult to use. If I used it all the time, it might be easier [to use correctly].” Finally, two participants asserted that all of the intervention components positively influenced their practice and thus did not offer any components that they perceived as having the least impact. Participant 2 claimed that “none of the activities had no impact. We are doing things so drastically different now [as a result of the intervention].” Therefore, according to the participants’ interview responses, additional training in the effective use of the RTOP instrument and Critical Thinking Grid may enhance the strength of the treatment effect on the participants’ instructional practice.

**Change.** The participants offered many suggestions for improving the program in the event that it would be implemented again in the future. Three participants felt that the timing of the professional development workshops should be adjusted to improve the program’s effectiveness. Two of these participants suggested that the workshops were too spread out and should be moved closer together. With too much spacing between the workshops, the two participants felt that teachers may tend to forget concepts from one workshop to the next. The third participant felt the workshops should be extended over
the entire school year to increase the program’s impact on teacher practice and student outcomes.

In addition, two participants suggested that the program should provide additional time for peer collaboration. A common and overwhelming theme that emerged from the interviews, support in the form of peer collaboration seemed to be an invaluable component of the program. By providing even more time for peer collaboration, the strength of the treatment effect may increase. Next, four participants acknowledged the need for further training in the instruments used during the intervention: two participants suggested that the program provide further training in using the RTOP, and two participants suggested that the program provide further training in using the Critical Thinking Grid (Foundation for Critical Thinking, 2007). With additional training, the participants asserted that they might more effectively use these instruments to improve their practice and student outcomes. For instance, Participant 1 explained that

The program could be extended over the entire year to be more helpful. You could then have additional time focused on using the RTOP and Critical Thinking Grid more effectively. You would also have additional time to review what you had worked on with your group, such as the critical thinking assignments and the lessons implemented. You could have additional time for checking in with your group to learn from each other.

Finally, two participants felt the intervention needed to provide more personalized support to facilitate the achievement of the teachers’ individual learning goals. They appreciated the support provided by the mentoring sessions and felt that having even
more time devoted to peer collaboration may further enhance their practice. For example, Participant 1 expressed that:

   It would be helpful to have additional time to work collaboratively during the workshops. We didn’t have time to work on some things during the workshops, and therefore we had to spend a decent amount of time outside the workshops [to work on our lesson plans].

Similarly, Participant 8 explained that “while it was helpful to break up into small groups in the workshops, you need more one-on-one attention in the workshops, more personalization to the teacher’s specific goals.”

   In the future, based on the interview feedback, program implementers may consider re-evaluating and adjusting the length of the program and timing of the workshops, providing additional training in the effective use of the RTOP and Critical Thinking Grid, and allotting additional time to peer collaboration and individualized support. By maintaining the core elements of the program while adapting it slightly to provide additional time and support in specific areas, the intervention may produce a stronger treatment effect.

Conclusion

   Both quantitative and qualitative sources provided data to evaluate the effectiveness of the professional development intervention. The quantitative results revealed mixed findings regarding the intervention’s effectiveness. Analyses of the teacher surveys suggest relatively strong knowledge of critical thinking among both treatment and control group participants at pre- and post-intervention, yet the quantitative results revealed no significant change in the participants’ knowledge of critical thinking
(RQ 1) after participating in the professional development program. However, in comparison to the control group, qualitative analysis of the open-ended survey question responses suggest improvement at post-intervention in the treatment group’s understanding of critical thinking. Similarly, while the quantitative survey results revealed no significant changes in the participants’ overall pedagogical beliefs (RQ 2) after participating in the intervention, multivariate analyses revealed a significant, positive effect on just two of the pedagogical belief indicators. Therefore, the results suggest that the intervention produced a small but noticeable impact (via the qualitative analyses) on the participants’ knowledge of critical thinking instruction (RQ 1), and a moderate, but significant, impact on the treatment group’s pedagogical beliefs (RQ 2) regarding the importance of critical thinking instruction and the need for teachers to receive training in critical thinking pedagogy.

In addition to the teacher surveys, the course evaluations administered to students in the participants’ science classes provided additional quantitative data on the intervention’s effectiveness. According to the T-test and ANCOVA analyses of the pre- and post-intervention course evaluation data, the student respondents observed no significant differences in their teachers’ critical thinking instructional practice over time. Therefore, according to the student respondents, the intervention did not produce an impact on teachers’ critical thinking instructional practice (RQ 3) over time.

The critical thinking assignments, administered at three time points during the intervention, provided yet another quantitative data set to evaluate the intervention’s effectiveness in producing positive change in the participants’ instructional practice (RQ 3). The students’ scores on the assignments, calculated using the Critical Thinking Grid
(Foundation for Critical Thinking, 2007), served as an indicator of the teachers’ adoption of critical thinking instructional practices over time. The treatment group’s mean assignment scores surpassed the control group’s scores at each of the three time-points and multivariate analyses revealed significant variance between the groups at the second time-point. In addition, linear regression analyses revealed a significant, positive association between time engaged in the intervention and the Critical Thinking Grid scores for the treatment group only.

Finally, the classroom observations, scored using the RTOP instrument, served as another quantitative indicator of the intervention’s effectiveness in promoting the participants’ adoption of critical thinking instructional practices over time. The univariate analyses of the pre- and post-intervention mean RTOP scores revealed promising results for the treatment group participants. While the control group members demonstrated teacher-centered (RTOP level II) instructional practices at both pre- and post-intervention, the treatment group members demonstrated a transition from teacher-centered (RTOP level II) to student-centered (RTOP level IV) instruction after participating in the intervention. The observed effect size (0.626) surpassed the desired effect size (0.42) and thus reflects the teachers’ effective adoption of practices that cultivate students’ critical thinking skills.

The semi-structured interviews conducted post-intervention with the treatment group participants provided additional, in-depth information to support and strengthen the quantitative findings. Qualitative analyses of the interview data revealed emergent themes regarding the intervention’s effectiveness. In particular, the respondents positively regarded the intervention’s ample allotment of time for practicing and
reflecting on the effective use of learned strategies; the support provided via group collaboration, peer feedback, and teaching resources; and, the intervention’s targeted focus on specific, relevant, and applicable instructional approaches that foster critical thinking development. In addition, the interview results supported a positive change in the respondents’: knowledge of critical thinking instruction (RQ 1), pedagogical beliefs (RQ 2), and classroom application of critical thinking instructional practices (RQ 3). The participants’ change in knowledge was indicated by their responses which demonstrated an enhanced understanding of pedagogical practices that foster students’ critical thinking development. The participants’ change in pedagogical beliefs was indicated by their responses which demonstrated an enhanced appreciation for the benefits of implementing in their classes the learned critical thinking approaches. And, the participants’ change in practice was indicated by their responses which demonstrated their increased use of critical thinking instructional approaches (e.g., IBL and PBL) that were learned during the intervention.

In addition to revealing emergent themes regarding the intervention’s effectiveness, a priori coding of the interview data elucidated the intervention components that most influenced the participants’ change in practice. The most influential components reflect the emergent themes of time, support, and focused. In particular, the participants identified the following components as being the most influential: group collaboration and support provided in the professional development workshops and mentoring sessions, time to practice the learned strategies, use of the RTOP instrument, peer observations, exemplar (video) lessons, and the critical thinking assignments. In addition, some participants suggested that increased time devoted to
training teachers in the effective use of evaluative instruments (namely RTOP and the Critical Thinking Grid) might improve the program in the future. Therefore, adjusting the program to provide teachers with additional time and support, without sacrificing its core structure, may further enhance its overall effectiveness.

**Discussion**

The mixed-methods research study findings indicate the extent to which the professional development intervention produced positive change in the participants’ knowledge of critical thinking instructional strategies (RQ 1; mediating variable), pedagogical beliefs (RQ 2; moderating variable), and adoption of critical thinking instructional practices (RQ 3; outcome variable). According to the findings, the intervention produced a minimal to moderate, positive change in the participants’ knowledge of critical thinking instructional practices; a significant, positive change in the participants’ pedagogical beliefs; and, a significant, positive change in the participants’ adoption of critical thinking instructional practices in classroom science lessons.

By modeling the cognitive apprenticeship framework, the intervention sought to positively influence the participants’ pedagogical practice via coaching, collaboration, application, peer feedback, and reflection (Collins, Brown, & Newman, 1989; Stewart & Lagowski, 2003). The research-based professional development program guided the participants through the four cognitive dimensions (*content, method, sequence, and sociology*) in order to positively influence their knowledge development, pedagogical beliefs, and critical thinking instructional practice (Collins et al., 1989). In alignment with the theoretical framework, a positive change in the participants’ knowledge and pedagogical beliefs about critical thinking instruction was expected to in turn lead to their
increased adoption of the promoted instructional practices (Abrami et al., 2015; Desimone et al., 2002; Duzor, 2011; Ertmer et al., 2012). As the participants progressed sequentially through the cognitive dimensions, they increased their knowledge of critical thinking and specific instructional strategies that foster critical thinking development (content); observed exemplar lessons, engaged in problem-solving activities that modeled the authentic application of the learned critical thinking strategies, and reflected on their pedagogical practice (method); practiced implementing the learned strategies in the authentic classroom context and engaged in small-group mentoring sessions to receive individualized support and peer feedback on their practice (sequence); and, collaborated with peers to discuss the effectiveness of their lessons and further develop their expertise in critical thinking instruction (sociology) (Collins et al., 1989). By modeling the cognitive apprenticeship framework, the intervention provided the time, support, and focus necessary to positively influence the participants’ critical thinking instructional practice.

In addition to modeling a cognitive apprenticeship framework, the intervention incorporated essential features of effective, research-based professional development programs. In particular, the ongoing nature of the program, combined with training in specific critical thinking instructional strategies and the allotment of time for practicing the learned strategies, enhanced the program’s overall effectiveness (Desimone et al., 2002). The researcher also aimed to strengthen the treatment effects by incorporating research-based features such as peer collaboration, peer observations, constructive feedback, and expert mentoring in critical thinking instruction (Abrami et al., 2015; Chong & Kong, 2012; Donaldson, 2013; Park et al., 2015; Paul & Elder, 2002).
Finally, the intervention incorporated features recommended by the critical thinking literature in order to optimize the treatment effect. In particular, the participants’ engagement in multiple workshops and mentoring sessions led by an expert in critical thinking served to promote their adoption of the learned strategies over time (Major & Palmer, 2006; Paul & Elder, 2002). In addition, the participants learned specific critical thinking instructional approaches that could be easily tailored to any of the science subject areas. Each of the critical thinking instructional approaches incorporated research-based components recommended by research in critical thinking development (Abrami et al., 2015). In particular, the approaches, as learned and practiced in the professional development intervention, incorporated the following components to cultivate the students’ critical thinking skills: authentic learning tasks, dialogue with peers, and mentoring by more knowledgeable peers or experts (Abrami et al., 2015).

Within the context of the professional development setting, the participants learned how to effectively implement in their classes research-based approaches for cultivating students’ critical thinking skills. In particular, the participants developed expertise in inquiry-based (IBL) and problem-based (PBL) learning, both critical thinking approaches which provide students with authentic learning experiences, encourage dialogue between students, and encourage students’ engagement with mentors who facilitate the learning process (Marshall & Horton, 2011; Sungur & Tekkaya, 2006). In addition, IBL promotes critical thinking development by performing inquiry tasks in the following order: engage, explore, explain, and extend (Franco, 2013; Marshall & Horton, 2011). In PBL, students work collaboratively to solve authentic problems while the teacher serves to facilitate the learning process (Sungur & Tekkaya, 2006). In both
instructional approaches, the students are at the center of learning, working collaboratively to construct their knowledge and achieve a common goal.

According to the research study findings, the intervention, while producing only moderate effects on teachers’ knowledge and beliefs, produced significant positive changes in the teachers’ critical thinking instructional practice. As mediating and moderating variables, respectively, pedagogical knowledge and beliefs were selected as intervention targets due to their direct causal link to instructional practice. However, the findings suggest that significant effects on teachers’ practice may still be attained in the absence of significant effects on pedagogical knowledge and beliefs. As observed in this study, the participants’ pre-intervention knowledge of critical thinking instruction suggested a relatively strong foundation for the effective application of critical thinking practices in the classroom context. Yet, the participants’ adherence to teacher-centered instructional practices, as observed at the pre-intervention time-point, failed to reflect their reported knowledge of student-centered practices that cultivate critical thinking. Furthermore, the participants’ reported student-centered pedagogical beliefs were not reflected in the traditional, teacher-centered practices observed at pre-intervention. Therefore, the findings suggest a missing link between the knowledge/pedagogical beliefs variables and the adoption of instructional practices variable.

The intervention’s effectiveness in producing positive change in the participants’ instructional practice suggests that the professional development program included an additional, critical link between the knowledge/pedagogical beliefs variables and the adoption of instructional practices variable. Because the findings suggest the participants possessed relatively strong knowledge of critical thinking instructional practices before
the intervention and experienced no significant change in this knowledge following the intervention, it may be concluded that simply possessing a strong knowledge-base is not enough to ensure the effective application of corresponding instructional strategies. Instead, teachers with a strong knowledge-base and student-centered pedagogical beliefs must be provided ample and targeted support to facilitate their translation of theory to practice. Possessing the requisite knowledge-base and pedagogical beliefs is an important first step; however, developing the skills to effectively apply the knowledge in specific contexts such that the desired student outcomes are achieved is imperative to the effective adoption of promoted instructional practices. While the study participants possessed a fairly strong knowledge-base and pedagogical beliefs in alignment with student-centered instruction, they were eager to learn strategies for effectively implementing student-centered practices in their unique classroom contexts. The intervention provided the participants with specific critical thinking instructional strategies and included components that supported their classroom application of these strategies.

As was expressed by the participants during the post-intervention interviews, the effectiveness of the intervention can be largely attributed to the program components that facilitated the application of the learned strategies in the teachers’ specific science contexts. The ongoing nature of the intervention provided ample time for the participants to practice the learned strategies within their authentic, classroom environment and reflect on their effectiveness in enhancing the students’ critical thinking outcomes. In addition, the intervention supported the participants’ application of the learned strategies by encouraging peer collaboration both in the professional development workshops and in small-group mentoring sessions. The participants’ engagement in peer observations
and their use of the RTOP instrument to provide feedback to their partner further enhanced their knowledge of strategies for effectively applying the critical thinking approaches in different contexts. Finally, by promoting instructional strategies that were relevant and adaptable to their subject area, the intervention encouraged the participants’ adoption and application of the approaches in their unique classroom contexts. Therefore, while the participants’ existing knowledge-base and pedagogical beliefs provided a strong and requisite foundation for adopting critical thinking instruction, the intervention provisions of time and support were crucial to ensuring the participants’ effective translation of theory to practice.

While the intervention effectively produced the desired mid-term outcome (teachers’ adoption of critical thinking instructional practices), it is important to acknowledge and address in future studies the limitations to the present study’s design. While the researcher took measures to reduce most threats to internal validity, threats to validity still existed given the study’s design. In the future, given that two participants withdrew from the study early on, additional steps must be taken to reduce the likelihood of attrition and the impact of attrition on the study outcomes. The use of the pretest-posttest control group design minimized the threats posed by attrition by providing preliminary data from which intervention effects could be estimated (Shadish et al., 2002). In addition, due to the participants’ close proximity and daily interactions within the intervention setting, some treatment diffusion (a threat to construct validity) did occur, causing the control group to become contaminated (Shadish et al., 2002). The diffusion of treatment to the control group may have diluted the strength of the observed effects, potentially leading to a Type II error in the findings (Shadish et al., 2002). While
preventing contamination would have been difficult given the intervention context, the study design did account for treatment diffusion by including questions in the post-intervention survey that assessed the level of contamination. In future studies, if contamination is detected, setting $\beta$ to a more conservative value (e.g., $\beta = 0.05$) when calculating effect size may decrease the probability of a Type II error while also increasing the statistical power (Lipsey, 1998).

Furthermore, the researcher’s role as the Chair of the Science Department must also be considered when interpreting the results of the present research study. While participation in the study was voluntary, it is possible that the science teachers felt more inclined to participate in the study and its various components given the researcher’s position as the Chair of the Science Department. In future studies, the relationship of the researcher with the participants should be considered and any bias generated due to this relationship minimized in order to increase the validity of the study results.

Finally, given the intervention’s small sample size (13), statistical conclusion validity was threatened due to increased sampling error and thus decreased statistical power (Shadish et al., 2002). Adequate power is needed in order to increase the probability of detecting significant intervention effects (Lipsey, 1998). While increasing the sample size would have increased statistical power by decreasing sampling error (Lipsey, 1998), the context of the study limited the number of available study participants. In addition, because the participants self-selected to the treatment or control group, sampling bias may have influenced the study results (Lipsey, 1998). In particular, the treatment group participants may have experienced enhanced professional growth due to their eagerness to learn novel instructional approaches. Therefore, additional
approaches may be taken to increase statistical power and thus the probability of
detecting intervention effects (Lipsey, 1998). For instance, identifying characteristics that
vary among the study participants and then selecting an appropriate statistical
significance test that “partitions them out of the error term” (p. 49) may increase
statistical power (Lipsey, 1998). In the present study, statistical power was increased by
ensuring a strong contrast between the treatment and control dosages and a high fidelity
of implementation across the conditions (Lipsey, 1998). Given adequate power, the study
design is more likely to answer the evaluation questions and detect significant effects of
intervention participation on the desired outcome: teachers’ adoption of critical thinking
instructional practices.

In future studies, in addition to taking measures to reduce any threats to validity, it
is recommended that minor adjustments be made to the intervention’s design in order to
enhance its effectiveness. While the core structure should remain the same, additional
provisions should be made to ensure the participants receive adequate training in the
effective use of the intervention instruments (i.e., the RTOP and Critical Thinking Grid).
With additional training in the valid and reliable use of these instruments, participants
may be more likely to maximize their effectiveness and enhance their application of the
promoted instructional strategies. Furthermore, if time in the school’s schedule permits,
the intervention may be prolonged over the entire school year in order to increase its
effect on teacher and student outcomes. However, the current spacing between the
workshops should be maintained (i.e., not lengthened) in order to optimize the level of
learning and recall from one workshop to the next.
Finally, it is recommended that the intervention be implemented in other contexts, to include other disciplines. A renowned feature of the promoted critical thinking strategies is their adaptability to other disciplines, not only the sciences. However, it is recommended that the intervention be tailored to specific disciplines and not implemented as a school-wide program. A critical ingredient of the intervention is its relevance and applicability to the participants’ specific content area and context. Therefore, broadening the intervention to the general, school-wide context might dilute its effectiveness and hinder the teachers’ effective application in their specific classroom contexts.

The intervention findings suggest the future may be bright for schools striving to keep pace with the rapidly evolving world of the 21st century. In private schools where autonomy and academic excellence are highly valued, teachers adhering to traditional practices may be just a small step away from transitioning to more effective pedagogical approaches. Assuming that most teachers in the private school context are presently increasing their knowledge of 21st century practices, an opportunity to engage in a professional development program of this nature and robustness may be the missing link that promotes their effective transfer of knowledge to the classroom context. In the private school setting, an intervention that embraces teacher autonomy while providing ongoing support to facilitate the teachers’ professional growth is crucial to remaining current and competitive in the 21st century. By implementing the present intervention, private schools can effectively support their teachers’ ongoing growth and, in turn, enhance their students’ outcomes in the 21st century.
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Footnotes

¹AIMS information retrieved from the official AIMS web site at

²Information confirmed by the Admissions and Guidance Departments at ICS.

³Demographic data and information regarding teacher credentials was retrieved from the ICS web site.
Appendix A

*Teacher Survey: Professional Development*

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<th>Question</th>
<th>Mean Response Score (5-point scale)</th>
<th>Number of Responses</th>
</tr>
</thead>
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<tr>
<td>3. My school uses a variety of data to monitor the effectiveness of professional development.</td>
<td>2.72</td>
<td>25</td>
</tr>
<tr>
<td>4. In my school, teachers have the opportunity to evaluate each professional development experience to determine its value and impact on student learning.</td>
<td>2.88</td>
<td>26</td>
</tr>
<tr>
<td>6. Student learning outcomes are used to determine my school’s professional development plan.</td>
<td>2.94</td>
<td>26</td>
</tr>
<tr>
<td>8. My school offers professional development opportunities that provide training in critical thinking instruction.</td>
<td>2.83</td>
<td>26</td>
</tr>
<tr>
<td>10. My school offers professional development opportunities that provide training in alternative assessment strategies (e.g., Project Based Learning, portfolios, debates, etc.).</td>
<td>2.76</td>
<td>26</td>
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**ANOVA**

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<th>Professional Development Q5</th>
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<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
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<tr>
<td>Between Groups</td>
<td>2.925</td>
<td>3</td>
<td>.975</td>
<td>3.232</td>
<td>.044</td>
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<td>Within Groups</td>
<td>6.033</td>
<td>20</td>
<td>.302</td>
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<td></td>
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<tr>
<td>Total</td>
<td>8.958</td>
<td>23</td>
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## Multiple Comparisons

Dependent Variable: Professional Development Q5

### Bonferroni

<table>
<thead>
<tr>
<th>(I) Content</th>
<th>(J) Content</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
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**ANOVA**

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Multiple Comparisons

Dependent Variable: Teacher Evaluations Q3

Bonferroni

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<td>12. Class time is best utilized for the delivery of content material to the students.</td>
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**Teacher Survey: Teacher Self-Efficacy**

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* The mean difference is significant at the 0.05 level.
**Teacher Survey: Collective Self-Efficacy**

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<td></td>
</tr>
<tr>
<td>Total</td>
<td>15.846</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Multiple Comparisons

Dependent Variable: Collective Self-Efficacy Q3

Bonferroni

<table>
<thead>
<tr>
<th>(I) Content</th>
<th>(J) Content</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Studies</td>
<td>Science</td>
<td>-.500</td>
<td>.380</td>
<td>1.000</td>
<td>-1.60</td>
<td>.60</td>
</tr>
<tr>
<td></td>
<td>English</td>
<td>-.400</td>
<td>.427</td>
<td>1.000</td>
<td>-1.64</td>
<td>.84</td>
</tr>
<tr>
<td></td>
<td>Math</td>
<td>.571</td>
<td>.392</td>
<td>.953</td>
<td>-.56</td>
<td>1.71</td>
</tr>
<tr>
<td>Science</td>
<td>Social Studies</td>
<td>.500</td>
<td>.380</td>
<td>1.000</td>
<td>-.60</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
<td>English</td>
<td>.100</td>
<td>.402</td>
<td>1.000</td>
<td>-1.06</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>Math</td>
<td>1.071*</td>
<td>.365</td>
<td>.046</td>
<td>.01</td>
<td>2.13</td>
</tr>
<tr>
<td>English</td>
<td>Social Studies</td>
<td>.400</td>
<td>.427</td>
<td>1.000</td>
<td>-.84</td>
<td>1.64</td>
</tr>
<tr>
<td></td>
<td>Science</td>
<td>-.100</td>
<td>.402</td>
<td>1.000</td>
<td>-1.26</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>Math</td>
<td>.971</td>
<td>.412</td>
<td>.167</td>
<td>-.22</td>
<td>2.17</td>
</tr>
<tr>
<td>Math</td>
<td>Social Studies</td>
<td>-.571</td>
<td>.392</td>
<td>.953</td>
<td>-1.71</td>
<td>.56</td>
</tr>
<tr>
<td></td>
<td>Science</td>
<td>-1.071*</td>
<td>.365</td>
<td>.046</td>
<td>-2.13</td>
<td>-.01</td>
</tr>
<tr>
<td></td>
<td>English</td>
<td>-.971</td>
<td>.412</td>
<td>.167</td>
<td>-2.17</td>
<td>.22</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the 0.05 level.

Teacher Survey: Demographics

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select the content area in which you primarily teach:</td>
<td>Social Studies</td>
<td>23.1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Science</td>
<td>30.8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>English</td>
<td>19.2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Math</td>
<td>26.9</td>
<td>7</td>
</tr>
</tbody>
</table>
Teacher Survey: Demographics

Select the content area in which you primarily teach:

![Pie chart](chart.png)

Graph generated by SurveyMonkey.com

Teacher Survey: Demographics

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you currently hold a teaching certification in your content area or are you currently working towards earning a teaching certification?</td>
<td>Yes</td>
<td>88.0</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>12.0</td>
<td>3</td>
</tr>
</tbody>
</table>
Teacher Survey: Demographics

Graph generated by SurveyMonkey.com

Teacher Survey: Demographics

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select the highest degree that you currently possess:</td>
<td>Associates degree</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Bachelor degree</td>
<td>4.2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Master degree</td>
<td>87.5</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Post-graduate degree</td>
<td>8.3</td>
<td>2</td>
</tr>
</tbody>
</table>
Teacher Survey: Demographics

Select the highest degree that you currently possess:

Graph generated by SurveyMonkey.com

Student Survey: Instructional Practices in Core Subject Areas

<table>
<thead>
<tr>
<th>Question</th>
<th>Math Mean Response Score</th>
<th>Social Studies Mean Response Score</th>
<th>English Mean Response Score</th>
<th>Science Mean Response Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. In my class, the teacher assigns hands-on activities.</td>
<td>3.11</td>
<td>3.30</td>
<td>3.46</td>
<td>4.29</td>
</tr>
<tr>
<td>4. In my class, the teacher assigns projects or other activities that require the students to work in teams.</td>
<td>2.18</td>
<td>3.50</td>
<td>3.67</td>
<td>4.16</td>
</tr>
<tr>
<td>5. In my class, the teacher uses lecture to present course material.</td>
<td>3.97</td>
<td>4.45</td>
<td>3.95</td>
<td>4.06</td>
</tr>
</tbody>
</table>
Student Survey: Critical Thinking Instructional Practices in Core Subject Areas

![Bar chart showing mean value scores for Math, Social Studies, English, and Science across different questions.](image-url)

- **Math**
  - Question 3: 3.0
  - Question 4: 3.5
  - Question 5: 1.5

- **Social Studies**
  - Question 3: 3.0
  - Question 4: 4.0
  - Question 5: 1.0

- **English**
  - Question 3: 3.0
  - Question 4: 4.0
  - Question 5: 1.5

- **Science**
  - Question 3: 4.0
  - Question 4: 4.5
  - Question 5: 2.0
**Logic Model**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
<th>Outcomes -- Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher participants: Science Department members</td>
<td>Pre- &amp; post-intervention surveys</td>
<td>Enhanced knowledge of CT instructional strategies</td>
</tr>
<tr>
<td>Student participants (Science classes)</td>
<td>Classroom observations (RTOP) performed by researcher</td>
<td>Increased adoption of CT instructional strategies</td>
</tr>
<tr>
<td>Researcher (Science Department Chair)</td>
<td>Professional Development workshops (x4)</td>
<td>Transition from teacher-centered to student-centered pedagogical beliefs</td>
</tr>
<tr>
<td>Time</td>
<td>Mentoring sessions (x4) provided by researcher</td>
<td>Students: Enhanced CT development</td>
</tr>
<tr>
<td>Technology resources: -Epson projectors -Laptops -Blackboard</td>
<td>Peer observations</td>
<td>Teachers: Increased effectiveness of implemented CT instructional strategies</td>
</tr>
<tr>
<td></td>
<td>Reflection on RTOP feedback</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CT assignments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-intervention interview</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science Course Evaluations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science Department members (14 total)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Treatment group members (7 Science Department members)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Students (Science Classes)</td>
<td></td>
</tr>
</tbody>
</table>
Logic Model - Continued

Assumptions
- The 15 Science Department members will participate in the study.
- The administrators will be supportive of the professional development intervention because of its alignment with the school-wide goal of developing students' 21st century skills (including critical thinking).
- The time slated for professional development will provide sufficient opportunities for teachers to learn, practice, and reflect on CT instructional strategies.
- Teachers will be honest when responding to survey questions, in spite of the researcher’s role as the Science Department Chairperson.

External Factors
- Teachers’ professional and personal responsibilities and other unforeseen circumstances may impact the teachers’ participation in the study.

Theory of Treatment
Appendix B

Teacher Informed Consent
Dissertation Research Study

Title: Investigating critical thinking instruction in the high school core content areas.

Principal Investigator: Molly Macek, Chair, Science Department

Purpose of Research Study:
The purpose of this research study is:

1) to determine the extent to which critical thinking instructional practices take place in the high school core content areas of science, math, social studies, and English; and,
2) to determine the extent to which school and teacher factors influence critical thinking instruction in the core content areas.

Procedure:
You will be asked to complete an electronic survey administered via Survey Monkey.

Time Required:
The survey will take approximately 10-15 minutes of your time.

Benefits:
This study will provide insight into the factors that influence the teacher’s instructional practices in his or her content area. The results of this study will inform the development of future strategies intended to enhance teacher effectiveness in the area of critical thinking instruction.

Voluntary Participation:
Your participation in this study is completely voluntary. There are no adverse consequences due to your lack of participation.

Confidentiality:
Your survey responses will be kept confidential to the extent possible by law. The survey data will be examined by the Principal Investigator only. The survey data will be collected electronically via a password protected Survey Monkey account. Identifiable information will be removed from any published reports of the survey data.
**Compensation:**

You will not receive any compensation for participation in this study.

If you have any questions about this research study, please contact Molly Macek via phone or email: (443) 286-9773 or macekm@notredameprep.com.

**Signatures:**

Your signature below indicates that you understand the information in this consent form and you agree to participate in this research study.

________________________
Participant’s Name

________________________
Participant’s Signature                  Date

________________________
Signature of Principal Investigator                  Date

(Molly Macek)
Teacher Survey

IA. Variable: Teacher Self-Efficacy Beliefs

Select from the following scale the option that best describes your belief about the statement:

(1) Not at all true  (2) Barely true  (3) Neutral  (4) Moderately true  (5) Exactly true

1. If I try hard enough, I know that I can exert a positive influence on both the personal and academic development of my students.
2. I am convinced that I can develop creative ways to cope with change and continue to teach well.
3. I know that I can motivate my students to participate in innovative projects.
4. I know that I can carry out innovative projects even when I am opposed by skeptical colleagues.
5. I feel confident to implement innovative instructional strategies even when skeptical colleagues do not see the value of these strategies.
6. Even if a new instructional strategy proves unsuccessful the first time I implement it, I am willing to take this risk in order to improve my practice.

IB. Variable: Collective Self-Efficacy Beliefs

Select from the following scale the option that best describes your belief about the statement:

(1) Not at all true  (2) Barely true  (3) Neutral  (4) Moderately true  (5) Exactly true

1. I believe in the potential of our school’s faculty to establish innovative approaches to education even when faced with setbacks.
2. I am certain that we, as teachers, can achieve educational goals because we stick together and do not get demoralized by the day-to-day challenges of this profession.
3. Our team of teachers can come up with creative ways to improve the school environment, even without support from others.
4. We are definitely able to accomplish something positive at school since we are a competent team of teachers that grows every time we are challenged.
5. As teachers, we can learn from our mistakes and setbacks in the classroom as long as we trust our shared competence.
6. I am certain that we can create a positive school climate through our shared efforts, even if this causes a tremendous workload for us.

II. Variable: Pedagogical beliefs

Select from the following scale the option that best describes your belief about the statement:

(1) Strongly Disagree  (2) Moderately Disagree  (3) Neutral  (4) Moderately Agree  (5) Strongly Agree
1. A teacher’s main goal is to prepare students to solve complex, real-life problems.
2. Encouraging students’ critical thinking skills is necessary.
3. Students should have opportunities to discover and construct concepts for themselves.
4. Content subjects should give students hands-on learning opportunities.
5. Meaningful activities and projects are important elements of instruction.
6. It is very helpful to involve students in small group discussions and cooperative learning activities.
7. Group projects should be used for individual student assessment.
8. Teachers should depend solely on tests for assessing student learning.
9. Alternative assessments, such as portfolios and projects, are valuable summative assessment options.
10. Projects are most valuable when assigned after the students have learned the content.
11. The time required to deliver content to the students limits the class time that can be devoted to projects.
12. Class time is best utilized for the delivery of content material to the students.
13. A measure of successful teaching is the ability to impart knowledge onto the students.
14. The student’s ability to apply prior knowledge to the construction of new concepts is an important skill in my content area.
15. The student’s ability to develop innovative solutions to novel problems is an important skill in my content area.
16. Depth of knowledge is more important than breadth of knowledge.

III. Variable: Professional Development

Select from the following scale the option that best describes your belief about the statement:

(1) Never   (2) Rarely   (3) Sometimes   (4) Often   (5) Always   (6) I don’t know

1. Practicing and applying new skills with students in my classroom are regarded as important learning experiences in my school.
2. Teachers in my school are involved in setting goals for professional development.
3. My school uses a variety of data to monitor the effectiveness of professional development.
4. In my school, teachers have the opportunity to evaluate each professional development experience to determine its value and impact on student learning.
5. In my school, teachers use what is learned from professional development to adjust and inform teaching practices.
6. Student learning outcomes are used to determine my school’s professional development plan.
7. Professional development in my school includes various forms of support to apply new practices in the classroom.
8. My school offers professional development opportunities that provide training in critical thinking instruction.
9. My school offers professional development opportunities that provide strategies for developing students’ higher-order thinking skills.
10. My school offers professional development opportunities that provide training in alternative assessment strategies (e.g., Project Based Learning, portfolios, debates, etc.).

IV. Variable: Teacher Evaluations & Feedback

Select from the following scale the option that best describes your belief about the statement:

(1) Never (2) Rarely (3) Sometimes (4) Often (5) Always (6) I don’t know

1. In my school, teachers give frequent feedback to colleagues to refine the implementation of instructional strategies.
2. Teachers in my school receive ongoing support in various ways to improve teaching.
3. All faculty members in my school are held to high standards to increase student learning.
4. In my school, teachers have a clear understanding of the evaluation criteria that are used to measure effectiveness in the classroom.
5. In my school, a teacher receives feedback, written or verbal, following an observation.
6. The feedback provided after an observation provides suggestions for improving the teacher’s overall practice.
7. The observation feedback provides suggestions for improving critical thinking instruction.
8. The observation feedback provides suggestions for developing the students’ higher-order thinking skills.
9. The observation feedback provides suggestions for projects or other alternative assessments for measuring student learning.

V. Variable: Teacher Collaboration in Academic Departments

Select from the following scale the option that best describes your belief about the statement:

(1) Never (2) Rarely (3) Sometimes (4) Often (5) Always

1. Teachers in my department engage in the continuous improvement cycle (i.e. data analysis, planning, implementation, reflection, and evaluation).
2. All members in my department hold each other accountable to achieve the school’s goals.
3. Members in my department meet several times per week to collaborate on how to improve student learning.
4. In my department, teachers demonstrate effective communication and relationship skills so that a high level of trust exists among the group.
5. My department as a whole embraces characteristics such as collaboration, high expectations, respect, trust, and constructive feedback.

VI. Variable: Teaching Experience/Credentials

1. Certification Status: Do you currently hold a teaching certification in your content area or are you currently working towards earning a teaching certification?
   a. Yes
   b. No

2. Education: Select the highest degree that you currently possess:
   a. Associates degree
   b. Bachelor degree
   c. Master degree
   d. Post-graduate degree (e.g., Ph.D.)

3. Content area: Select the content area in which you primarily teach:
   a. Social Studies
   b. Science
   c. English
   d. Math

4. Experience: How many years have you been a teacher?
   a. Less than 1 year
   b. 1-4 years
   c. 5-10 years
   d. 11-16 years
   e. 17-25 years
   f. More than 25 years

5. Experience at current school: How many years have you been teaching at your current school?
   a. 0-1 years
   b. 2-4 years
   c. 5-9 years
   d. 10-20 years
   e. 21 or more years
Student Assent and Parental Informed Consent
Dissertation Research Study

Title: Investigating critical thinking instruction in the high school core content areas.

Principal Investigator: Molly Macek, Chair, Science Department

Purpose of Research Study:
The purpose of this research study is to determine, from the student’s perspective, the extent to which critical thinking instructional practices take place in the high school core content areas of science, math, social studies, and English.

Procedure:
Your daughter will be asked to complete one brief survey, administered via Survey Monkey.

Time Required:
The survey will take no more than 10 minutes of your daughter’s time.

Benefits:
This study will provide insight into the types of instruction and learning opportunities that occur in your daughter’s science, math, social studies, and English classes. The results of the study will inform the development of future strategies intended to improve instruction and student achievement.

Voluntary Participation:
Your daughter’s participation in this study is completely voluntary. There are no adverse consequences due to your daughter’s lack of participation.

Confidentiality:
The survey data submitted by your daughter will be kept confidential to the extent possible by law. The survey data will be examined by the Principal Investigator only. The survey data will be collected electronically via a password protected Survey Monkey account that belongs to Notre Dame Preparatory School. Identifiable information will be removed from any published reports of the survey data.

Compensation:
Your daughter will not receive any compensation for participation in this study.
If you have any questions or concerns:

If you or your daughter have any questions about this research study, please contact Molly Macek via phone or email: (443) 286-9773 or macekm@notredameprep.com.

Signatures:

Your signature below indicates that:

1) you understand the information in this consent form, and
2) you agree to allow your child to participate in this study.

Your daughter’s signature below indicates that she agrees to participate in the study.

________________________________________
Child’s Name

________________________________________
Child’s Signature Date

________________________________________
Signature of Parent or Legal Guardian Date

________________________________________
Signature of Principal Investigator Date
(Molly Macek)
Student Survey

Part I. Instructional Practices

A. SCIENCE

Select from the following scale the option that best describes your experience in your SCIENCE class.

Note: If you are not currently enrolled in a science course, please select “Not Applicable” for the items. If you are currently enrolled in more than one science course, please decide on one course for which you will rate the items below.

(1) Never (2) Rarely (3) Sometimes (4) Often (5) Always (6) Not Applicable

In my SCIENCE class, my teacher:

1. designs lessons that build upon my prior knowledge and experiences.
2. sets high expectations in order to challenge and stimulate the students.
3. assigns hands-on activities in class.
4. assigns projects or other activities that require the students to work in teams.
5. uses lecture to present the course material.
6. challenges me to perform to my greatest potential.
7. challenges the students to use their prior knowledge to solve complex problems.
8. strives to engage the students by asking challenging questions and encouraging class discussions.
9. assigns activities or asks questions that challenge me to apply higher-order thinking skills (e.g., solve problems, analyze information, critically evaluate concepts, etc.).

B. MATH

Select from the following scale the option that best describes your experience in your MATH class.

Note: If you are currently enrolled in more than one math course, please decide on one course for which you will rate the items below.

(1) Never (2) Rarely (3) Sometimes (4) Often (5) Always (6) Not Applicable

In my MATH class, my teacher:

1. designs lessons that build upon my prior knowledge and experiences.
2. sets high expectations in order to challenge and stimulate the students.
3. assigns hands-on activities in class.
4. assigns projects or other activities that require the students to work in teams.
5. uses lecture to present the course material.
6. challenges me to perform to my greatest potential.
7. challenges the students to use their prior knowledge to solve complex problems.
8. strives to engage the students by asking challenging questions and encouraging class discussions.
9. assigns activities or asks questions that challenge me to apply higher-order thinking skills (e.g., solve problems, analyze information, critically evaluate concepts, etc.).

C. ENGLISH

Select from the following scale the option that best describes your experience in your ENGLISH class.

Note: If you are currently enrolled in more than one English course, please decide on one course for which you will rate the items below.

(1) Never   (2) Rarely   (3) Sometimes   (4) Often   (5) Always   (6) Not Applicable

In my ENGLISH class, my teacher:

1. designs lessons that build upon my prior knowledge and experiences.
2. sets high expectations in order to challenge and stimulate the students.
3. assigns hands-on activities in class.
4. assigns projects or other activities that require the students to work in teams.
5. uses lecture to present the course material.
6. challenges me to perform to my greatest potential.
7. challenges the students to use their prior knowledge to solve complex problems.
8. strives to engage the students by asking challenging questions and encouraging class discussions.
9. assigns activities or asks questions that challenge me to apply higher-order thinking skills (e.g., solve problems, analyze information, critically evaluate concepts, etc.).

D. SOCIAL STUDIES

Select from the following scale the option that best describes your experience in your SOCIAL STUDIES class.

Note: If you are currently enrolled in more than one social studies course, please decide on one course for which you will rate the items below.

(1) Never   (2) Rarely   (3) Sometimes   (4) Often   (5) Always   (6) Not Applicable

In my SOCIAL STUDIES class, my teacher:

1. designs lessons that build upon my prior knowledge and experiences.
2. sets high expectations in order to challenge and stimulate the students.
3. assigns hands-on activities in class.
4. assigns projects or other activities that require the students to work in teams.
5. uses lecture to present the course material.
6. challenges me to perform to my greatest potential.
7. challenges the students to use their prior knowledge to solve complex problems.
8. strives to engage the students by asking challenging questions and encouraging class discussions.
9. assigns activities or asks questions that challenge me to apply higher-order thinking skills (e.g., solve problems, analyze information, critically evaluate concepts, etc.).

Part II: Subject Area & Level

1. Select your current grade level:
   a. 9th
   b. 10th
   c. 11th
   d. 12th

2. Select the Science course in which you are currently enrolled (only select the course for which you rated the survey items):
   a. Biology phase 3
   b. Biology phase 4
   c. Biology phase 5
   d. Chemistry phase 3
   e. Chemistry phase 4
   f. Chemistry phase 5
   g. Physics phase 3
   h. Physics phase 4
   i. Physics phase 5
   j. Anatomy & Physiology phase 3
   k. Anatomy & Physiology phase 4
   l. Anatomy & Physiology phase 5
   m. Environmental Science
   n. Forensic Science
   o. AP Biology
   p. AP Chemistry
   q. AP Physics I
   r. AP Physics II
   s. AP Environmental Science
   t. Other:
      u. I am not currently enrolled in a Science course

3. Select the Math course in which you are currently enrolled (only select the course for which you rated the survey items):
   a. Algebra I phase 2
   b. Algebra I phase 3
c. Algebra I phase 4
d. Geometry phase 2
e. Geometry phase 3
f. Geometry phase 4
g. Geometry phase 5
h. Geometry/Trigonometry
i. Algebra II phase 2
j. Algebra II phase 3
k. Algebra II phase 4
l. Algebra II phase 5
m. Pre-Calculus/Trigonometry
n. Pre-Calculus/Analytic Geometry
o. Introduction to Statistics and Math Modeling
p. Pre-Calculus phase 4
q. Pre-Calculus phase 5
r. Calculus I
s. AP Calculus I
t. AP Calculus II
u. AP Statistics
v. Other:
w. I am not currently enrolled in a Math course

4. Select the English course in which you are currently enrolled (only select the course for which you rated the survey items):
   a. English 9 phase 2
d. English 9 phase 5
e. English 10 phase 2
f. English 10 phase 3
g. English 10 phase 4
h. English 10 phase 5
i. English 10 – Humanities phase 3
j. English 10 – Humanities phase 4
k. English 11 phase 3
l. English 11 phase 4
m. English 11 PARALLEL American Literature/U.S. History
n. English 11 – Humanities phase 3
o. English 11 – Humanities phase 4
p. English 12: Myths & Monsters
q. English 12: Shakespearean Drama
r. A.P. English
s. Creative Writing
t. Creative Communication
u. Theatre Experience
v. Other:
w. I am not currently enrolled in an English course

5. Select the Social Studies course in which you are currently enrolled (only select the course for which you rated the survey items):
a. World Cultures phase 2
b. World Cultures phase 3
c. World Cultures phase 4
d. World Cultures phase 5
e. U.S. History I & Government phase 2
f. U.S. History I & Government phase 3
g. U.S. History I & Government phase 4
h. U.S. History I & Government phase 5
i. U.S. History I & Government – Humanities
j. U.S. History II & Government phase 3
k. U.S. History II & Government phase 4
l. U.S. History II & Government – Humanities
m. AP U.S. History II/American Literature PARALLEL
n. AP U.S. History II
o. Civil Liberties/Women’s Studies
p. AP U.S. Government & Politics
q. AP Micro/Macro Economics: Principles & Practices
r. Contemporary World Issues
s. Based On a True Story (B.O.A.T.S.) Historical Research
t. Applied Economics
u. Other:
v. I am not currently enrolled in a Social Studies course
Appendix C

Teacher Survey: Pre- and Post-Intervention

Part I. Demographics (Pre-intervention only; treatment & control groups)

1. **Subject area**: Select all of the science subjects that you currently teach:
   f. Biology
   g. Chemistry
   h. Physics
   i. Environmental Science
   j. Forensic Science
   k. Anatomy & Physiology
   l. Biotechnology
   m. Engineering
   n. AP Biology
   o. AP Chemistry
   p. AP Environmental Science
   q. AP Physics I
   r. AP Physics II

2. **Experience**: How many years have you been a teacher?
   a. Less than 1 year
   b. 1-4 years
   c. 5-10 years
   d. 11-16 years
   e. 17-25 years
   f. More than 25 years

3. **Experience at current school**: How many years have you been teaching at your current school?
   a. 0-1 years
   b. 2-4 years
   c. 5-9 years
   d. 10-20 years
   e. 21 or more years
Part II. Critical Thinking Pedagogy (Pre- & post-intervention: Treatment & control groups)

Select from the following scale the option that best describes your belief about the statement:

(1) Strongly Disagree  (2) Somewhat Disagree  (3) Neutral  (4) Somewhat Agree  (5) Strongly Agree

1. I have a clear idea of what the term “critical thinking” means.
2. Teaching critical thinking skills is an important part of my job as a teacher.
3. I build critical thinking explanations and exercises into most of my lessons.
4. Students at this school in general are good at critical thinking.
5. It is not necessary to increase the role of critical thinking into the curriculum.
6. It is not the job of the teacher to teach critical thinking in the classroom.
7. Critical thinking is especially important in the subject that I teach.
8. Teachers need more training about how to teach critical thinking skills.
   (Isikoglu et al., 2009)
9. Students should have opportunities to pose questions, discover and construct concepts for themselves.
10. Students should construct their own meaning.
11. Teachers’ main responsibility is to transmit knowledge and skills.
12. It is very helpful to involve students in small group discussions and cooperative learning.
13. Group projects should be used for individual student assessment.
14. Portfolios, rubrics and exhibitions should be used for assessment.
   (Stapleton, 2011)

Select the response that best characterizes the extent to which your science classes, in general, incorporate the activities described in the statements below.

(1) Never  (2) Rarely  (3) Sometimes  (4) Often  (5) Always

15. In my classes, student exploration precedes formal presentation of content.
16. In my classes, lessons encourage students to seek alternative modes of problem solving.
17. In my classes, students make connections with other content disciplines and/or real world phenomena.
18. In my classes, students use a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.
19. In my classes, students engage in thought-provoking activities that involve the critical assessment of procedures.
20. In my classes, students make predictions, estimations, and/or hypotheses and devise means for testing them.
21. In my classes, students are reflective about their learning.
22. In my classes, intellectual rigor, constructive criticism, and the challenging of ideas are valued.  
(Sawada et al., 2002)

23. Complete the phrase: A good critical thinker is a person who…  
(Stapleton, 2011)

Part III: Involvement in Program Components

(Post-intervention; Treatment group only)

Use the following scale to rate the extent to which your involvement in the stated program component positively influenced your ability to teach in a manner that cultivates your students’ critical thinking skills (1 = no influence; 4 = most positive influence; 5 = no basis for rating because I did not engage in this activity):

(1) No influence  (2) Minor influence  (3) Moderate influence  (4) Strong influence  (5) I don’t know; I did not participate in the activity

24. Professional Development Workshops

25. Mentoring sessions with the researcher only

26. Mentoring sessions with the researcher and my peers who observed my lessons

27. Performing observations of my peers

28. Being observed by my peers

29. Individually reflecting on my RTOP feedback

30. Collectively reflecting on my RTOP feedback with the researcher and/or my peers

31. In the professional development workshops, group discussions on our instructional practice

32. In the professional development workshops, learning about the components of critical thinking (elements of thought, universal intellectual standards, intellectual traits)

33. In the professional development workshops, learning about the different types of critical thinking instruction, including inquiry-based and problem-based learning
34. In the professional development workshops, watching videos that modeled critical thinking instructional approaches

35. Using the “Criteria for Critical Thinking Assignments” worksheet to design and implement critical thinking assignments in my classes

36. Using the “Critical Thinking Grid” (rubric) to evaluate the students’ work on the critical thinking assignments I designed

37. In the professional development workshop, comparing my student work samples with those of my colleagues as we discussed the effectiveness of the critical thinking assignments

*Use the following scale to respond to the last two questions:*

(1) Never  (2) Rarely  (3) Sometimes  (4) Often  (5) Always

38. To what extent did you share information learned from the professional development workshops with science department members who did NOT participate in the program?

39. To what extent did you share information learned from the mentoring sessions with science department members who did NOT participate in the program?
COURSE EVALUATION FORM:
Student Perceptions of Critical Thinking in Instruction

INSTRUCTOR ________________________________________________

Course Number and Title ________________________________________

Instructions: Do not put your name on this sheet. Circle appropriate number for each item.

1) To what extent does the instructor teach so that you must THINK to understand the content, or are you able to get a good grade by simply memorizing without really understanding the content? 1 2 3 4 5

2) To what extent did your instructor explain what critical thinking is (in a way that you could understand)? 1 2 3 4 5

3) To what extent does your instructor teach so as to encourage critical thinking in the learning process? 1 2 3 4 5

4) To what extent does your instructor teach so as to make clear the reason why you are doing what you are doing (the purpose of the assignment, activity, chapter, test, etc…)? 1 2 3 4 5

5) To what extent does your instructor teach so as to make clear the precise question, problem, or issue on the floor at any given time in instruction? 1 2 3 4 5

6) To what extent does your instructor teach so as to help you learn how to find information relevant to answering questions in the subject? 1 2 3 4 5

7) To what extent does your instructor teach so as to help you learn how to understand the key organizing concepts in the subject? 1 2 3 4 5

8) To what extent does your instructor teach so as to help you learn how to identify the most basic assumptions in the subject? 1 2 3 4 5
9) To what extent does your instructor teach so as to help you learn how to make inferences justified by data or information?

1 2 3 4 5

10) To what extent does your instructor teach so as to help you learn how to distinguish assumptions, inferences, and implications?

1 2 3 4 5

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<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>To what extent does your instructor teach so as to help you learn how to think within the point of view of the subject (think historically, think scientifically, think mathematically)?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>To what extent does your instructor teach so as to help you learn how to ask questions that experts in the subject routinely ask?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>To what extent does your instructor teach so as to enable you to think more clearly?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>To what extent does your instructor teach so as to enable you to think more accurately?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>To what extent does your instructor teach so as to enable you to think more deeply?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>To what extent does your instructor teach so as to enable you to think more logically?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17</td>
<td>To what extent does your instructor teach so as to enable you to think more fairly?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>To what extent does your instructor teach so as to help you learn how to distinguish what you know from what you don’t know?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19</td>
<td>To what extent does your instructor teach so as to help you learn how to think within the point of view of those with whom you disagree?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
20) To what extent does your instructor teach so as to encourage you to think for yourself using intellectual discipline?

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Criteria for Critical Thinking Assignments

Faculty should design critical thinking assignments with the following criteria in mind. Assignments must meet all four criteria to be considered “standard.”

1. **Critical thinking assignments should address fundamental & powerful concepts and should be substantive and meaningful.**

   List the fundamental and powerful concepts addressed in the assignment.

2. **Critical thinking assignments should require students to use appropriate cognitive skills.**

   Using the attached checklist of critical thinking skills and abilities, identify those skills that are required to complete the assignment.

3. **Critical thinking assignments should hold students’ thinking to intellectual standards.**

   List the intellectual standards relevant to the assignment.

4. **Critical thinking assignments should ask questions requiring reasoned judgment within conflicting systems or complex questions requiring evidence and reasoning within one system.**

   List the assignment question(s).

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Cognitive Skills that Underlie Critical Thinking

___demonstrate a clear understanding of the assignment’s purpose
___clearly define the issue or problem
___accurately identify the core issues
___appreciate depth and breadth of the problem
___demonstrate fair-mindedness toward the problem
___identify and evaluate relevant significant points of view
___examine relevant points of view fairly, empathetically
___gather sufficient, credible, relevant information: observations, statements, logic, data, facts, questions, graphs, themes, assertions, descriptions, etc.
___include information that opposes as well as supports the argued position
___distinguish between information and inferences drawn from that information
___identify and accurately explain/use relevant key concepts
___accurately identify assumptions (things taken for granted)
___make assumptions that are consistent, reasonable, and valid
___follow where evidence and reason lead in order to obtain defensible, thoughtful, logical conclusions or solutions
___make deep rather than superficial inferences
___make inferences that are consistent with each other
___identify the most significant implications and consequences of the reasoning (whether positive and/or negative)
___distinguish probable from improbable implications

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## Critical Thinking Grid

<table>
<thead>
<tr>
<th>Purpose</th>
<th>4 - Exemplary</th>
<th>3 - Satisfactory</th>
<th>2- Below Satisfactory</th>
<th>1 - Unsatisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>--Demonstrates a clear understanding of the assignment’s purpose</td>
<td>--Demonstrates an understanding of the assignment’s purpose</td>
<td>--Is not completely clear about the purpose of the assignment</td>
<td>--Does not clearly understand the purpose of the assignment</td>
<td></td>
</tr>
<tr>
<td>--Appreciates depth and breadth of problem</td>
<td>--Defines the issue; identifies the core issues, but may not fully explore their depth and breadth</td>
<td>--Defines the issue, but poorly (superficially, narrowly); may overlook some core issues</td>
<td>--Fails to clearly define the issue or problem; does not recognize the core issues</td>
<td></td>
</tr>
<tr>
<td>--Demonstrates fairness-mindedness toward problem</td>
<td>--Demonstrates fairness-mindedness</td>
<td>--Has trouble maintaining a fair-minded approach toward the problem</td>
<td>--Fails to maintain a fair-minded approach toward the problem</td>
<td></td>
</tr>
</tbody>
</table>

| Key Question, Problem, or Issue                                       | --Clearly defines the issue or problem; accurately identifies the core issues | --Defines the issue; identifies the core issues, but may not fully explore their depth and breadth | --Defines the issue, but poorly (superficially, narrowly); may overlook some core issues | --Fails to clearly define the issue or problem; does not recognize the core issues |
| --Appreciates depth and breadth of problem                             | --Demonstrates fairness-mindedness | --Has trouble maintaining a fair-minded approach toward the problem | --Fails to maintain a fair-minded approach toward the problem |

| Point of View                                                          | --Identifies and evaluates relevant significant points of view | --Identifies and evaluates relevant points of view | --May identify other points of view but struggles with maintaining fairness-mindedness; may focus on irrelevant or insignificant points of view | --Ignores or superficially evaluates alternate points of view |
| --Is empathetic, fair in examining all relevant points of view         | --Is fair in examining those views | | --Cannot separate own vested interests and feelings when evaluating other points of view |

<p>| Information                                                             | --Gathers sufficient, credible, relevant information: observations, statements, logic, data, facts, questions, graphs, themes, assertions, descriptions, etc. | --Gathers sufficient, credible, and relevant information | --Gathers some credible information, but not enough; some information may be irrelevant | --Relies on insufficient, irrelevant, or unreliable information |
| --Includes information that opposes as well as supports the argued position | --Includes some information from opposing views | --Omits significant information, including some strong counter-arguments | --Fails to identify or hastily dismisses strong, relevant counter-arguments |
| --Distinguishes between information and inferences drawn from that information | --Distinguishes between information and inferences drawn from it | --Sometimes confuses information and the inferences drawn from it | --Confuses information and inferences drawn from that information |</p>
<table>
<thead>
<tr>
<th>Concepts</th>
<th>Identifies and accurately explains/uses the relevant key concepts</th>
<th>Identifies and accurately explains and uses the key concepts, but not with the depth and precision of a “4”</th>
<th>Identifies some (not all) key concepts, but use of concepts is superficial and inaccurate at times</th>
<th>Misunderstands key concepts or ignores relevant key concepts altogether</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumptions</td>
<td>Accurately identifies assumptions (things taken for granted)</td>
<td>Identifies assumptions</td>
<td>Fails to identify assumptions, or fails to explain them, or the assumptions identified are irrelevant, not clearly stated, and/or invalid</td>
<td>Fails to identify assumptions</td>
</tr>
<tr>
<td></td>
<td>Makes assumptions that are consistent, reasonable, valid</td>
<td>Makes valid assumptions</td>
<td></td>
<td>Makes invalid assumptions</td>
</tr>
<tr>
<td>Interpretations, Inferences</td>
<td>Follows where evidence and reason lead in order to obtain defensible, thoughtful, logical conclusions or solutions</td>
<td>Follows where evidence and reason lead to obtain justifiable, logical conclusions</td>
<td>Does follow some evidence to conclusions, but inferences are more often than not unclear, illogical, inconsistent, and/or superficial</td>
<td>Uses superficial, simplistic, or irrelevant reasons and unjustifiable claims</td>
</tr>
<tr>
<td></td>
<td>Makes deep rather than superficial inferences</td>
<td>Makes valid inferences, but not with the same depth and as a “4”</td>
<td></td>
<td>Makes illogical, inconsistent inferences</td>
</tr>
<tr>
<td></td>
<td>Makes inferences that are consistent with one another</td>
<td></td>
<td></td>
<td>Exhibits closed-mindedness or hostility to reason; regardless of the evidence, maintains or defends views based on self-interest</td>
</tr>
<tr>
<td>Implications, Consequences</td>
<td>Identifies the most significant implications and consequences of the reasoning (whether positive and/or negative)</td>
<td>Identifies significant implications and consequences and distinguishes probable from improbable implications, but not with the same insight and precision as a “4”</td>
<td>Has trouble identifying significant implications and consequences; identifies improbable implications</td>
<td>Ignores significant implications and consequences of reasoning</td>
</tr>
<tr>
<td></td>
<td>Distinguishes probable from improbable implications</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Critical Thinking Worksheet

### Overall Score ______

<table>
<thead>
<tr>
<th>If applicable, score the element (1-4)</th>
<th>Element of Reasoning</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong>: Does the student demonstrate a clear understanding of the assignment’s purpose?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Key Question, Problem, or Issue</strong>: Does the student clearly define the issue or problem, accurately identify the core issues, appreciate their depth and breadth?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Point of View</strong>: Does the student identify and evaluate relevant significant points of view? Does the student demonstrate fairmindedness toward the problem?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Information</strong>: Does the student gather sufficient, credible, relevant information (statements, logic, data, facts, questions, graphs, assertions, observations, etc.)? Does the student include information that opposes as well as supports the argued position? Does the student distinguish between information and inferences drawn from that information?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Concepts</strong>: Does the student identify and accurately explain/use the relevant key concepts?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Assumptions</strong>: Does the student accurately identify assumptions (things taken for granted)? Does the student make assumptions that are consistent, reasonable, valid?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interpretations, Inferences</strong>: Does the student follow where evidence and reason lead in order to obtain defensible, thoughtful, logical conclusions or solutions? Does the student make deep (rather than superficial) inferences? Are the inferences consistent?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Implications, Consequences</strong>: Does the student identify the most significant implications and</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
consequences? Does the student distinguish probable from improbable implications?

Critical Thinking Worksheet

Scoring Guidelines

4 = Thinking is exemplary, skilled, marked by excellence in clarity, accuracy, precision, relevance, depth, breadth, logicality, and fairness

3 = Thinking is competent, effective, accurate and clear, but lacks the exemplary depth, precision, and insight of a 4

2 = Thinking is inconsistent, ineffective; shows a lack of consistent competence: is often unclear, imprecise, inaccurate, and superficial

1 = Thinking is unskilled and insufficient, marked by imprecision, lack of clarity, superficiality, illogicality, and inaccuracy, and unfairness

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Science Lesson Template

This lesson template should be completed and submitted to the evaluator prior to the scheduled formal observation.

I. Lesson Objective:

II. Overview of lesson/learning activities:

III. List and describe the activities intended to foster the students’ critical thinking development (include inquiry- and/or problem-based approaches here):

IV. Student work to be submitted (should provide evidence of the students’ application of critical thinking to deepen their understanding of the concepts covered in the lesson):
V. Place a check next to each of the cognitive skills (Foundation for Critical Thinking) that your students will apply during the lesson:

___demonstrate a clear understanding of the assignment’s purpose
___clearly define the issue or problem
___accurately identify the core issues
___appreciate depth and breadth of the problem
___demonstrate fair-mindedness toward the problem
___identify and evaluate relevant significant points of view
___examine relevant points of view fairly, empathetically
___gather sufficient, credible, relevant information: observations, statements, logic, data, facts, questions, graphs, themes, assertions, descriptions, etc.
___include information that opposes as well as supports the argued position
___distinguish between information and inferences drawn from that information
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___make assumptions that are consistent, reasonable, and valid
___follow where evidence and reason lead in order to obtain defensible, thoughtful, logical conclusions or solutions
___make deep rather than superficial inferences
___make inferences that are consistent with each other
___identify the most significant implications and consequences of the reasoning (whether positive and/or negative)
___distinguish probable from improbable implications
I. Lesson Design and Implementation

1. The instructional strategies and activities respected students’ prior knowledge and the preconceptions inherent therein.
   a. Score of 4 because the entire lesson was set up for the students to build upon prior understanding.

2. The lesson was designed to engage students as members of a learning community.
   a. Score of 3 because there was not enough student-to-student development of ideas. There was good student to teacher interaction and development of ideas. This would give a 2 but there was some student-to-student interaction and discourse over describing the phenomenon, but little or no evidence for student-to-student construction of ideas and understanding.

3. In this lesson, student exploration preceded formal presentation.
   a. Score of 3 because although there was little introduction of concepts before student exploration, the teacher did mention that was going to happen in an aside.

4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.
   a. Score of 2 because the teacher solicited different answers but the teacher while not condemning the alternative placement of the blocks, encourages all the students to look straight through the thick side and to draw the situation from the top down.

5. The focus and direction of the lesson was often determined by ideas originating with students.
   a. Score of 2 because the teacher directed the lesson rather strongly. The teacher set the agenda and showed the students the observations and did not get the students to direct their own participation.

II. Content: Propositional Knowledge

1. The lesson involved fundamental concepts of the subject.
   a. Score of 4 because this is a science course for pre-service elementary teachers. The Arizona Science Standards have optics as a topic for elementary teachers to teach.

2. The lesson promoted strongly coherent conceptual understanding.
   a. Score of 2 because there were phenomena described and some articulation of the description but there was little concept building.

3. The teacher had a solid grasp of the subject matter content inherent in the lesson.
   a. Score of 4 because he didn’t make any factual errors and responded to the student questions with correct answers.
4. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.
   a. Score of 3 because the teacher made good use of drawings and focused the students on the rays at the critical interfaces and focused the students on the normal. But no real theory was developed, the phenomenon was described and drawn.
5. Connections with other content disciplines and/or real phenomena were explored and valued.
   a. Score of 2 because the students are working with an everyday phenomenon, but he did not have relevance to everyday life. Could have used an example like the windshield is engineered to help minimize this.

III. Content: Procedural Knowledge

1. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.
   a. Score of 3 because even though the phenomenon was represented in many different ways by the instructor, the students represented the phenomenon only with the prism and drawing. The students could have been encouraged to tell where else does this happen. Questions like this one and the resultant behaviors would increase the instructors’ score not only on item 1 (part III), but also on several items including 10 (part II) and 17 (part IV).
2. Students made predictions, estimations and/or hypotheses and devised means for testing them.
   a. Score of 0 because the students did not make predictions and did not test ideas for validity.
3. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.
   a. Score of 1 because the students were actively engaged but the students did not consider how they were doing the activity, or how this could be changed.
4. Students were reflective about their learning.
   a. Score f 1 because there was evidence from the female student giving the explanation at the end that she was thinking about how she understood the phenomenon but there was no evidence that the majority of the students were “thinking about their thinking”.
5. Intellectual rigor, constructive criticism, and the challenging of ideas were valued.
   a. Score of 1 because there was some articulation of the group ideas but competing ideas were not even offered.
IV. Classroom Culture: Communicative Interactions

1. Students were involved in the communication of their ideas to others using a variety of means and media.
   a. Score of 3 because there was within group communication using drawings and protractors to measure and quantify. There was some between group communications, but not to the group as a whole.

2. The teacher’s questions triggered divergent modes of thinking.
   a. Score of 2 because the instructor’s set-up was divergent but it was clear the teacher was looking for a specific answer.

3. There was a high proportion of student talk and a significant amount of it occurred between and among students.
   a. Score of 2 because the class had a lot of student talking while the teacher moved around to various groups but the teacher also did a lot of talking.

4. Student questions and comments often determined the focus and direction of classroom discourse.
   a. Score of 3 because the students are discussing in their groups and with the teacher. This discourse is central to the development of the description of phenomenon. The teacher asks the students anything else to add and the teacher answers several student questions, which were not central to the idea he was doing. There needed to be more group to teacher discourse and group-to-group.

5. There was a climate of respect for what others had to say.
   a. Score of 3 because the teacher closed down some of the student exploration (position of block, etc.)

V. Student/Teacher Relationships

1. Active participation of students was encouraged and valued.
   a. Score of 2 because students were encouraged to describe the phenomenon but not explain it on their own. The teacher actually described the phenomenon for the students before he asked for their descriptions.

2. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.
   a. Score of 1 because there was one “right” answer but it was derived from the students’ work. For the teacher, there was only one path students should be taking.

3. In general the teacher was patient with students.
   a. Score of 2 because the teacher missed the opportunity to capitalize on the students trying the block in different orientations. The teacher could have looked at why the effect is more pronounced in the edge on view compared to the top rotation.
4. The teacher acted as a resource person, working to support and enhance student investigations.
   a. Score of 3 because there is a lot of evidence for teacher’s interactions with the groups, the teacher is too often answering questions instead of directing inquiry.

5. The metaphor “teacher as listener” was very characteristic of this classroom.
   a. Score of 3 because the teacher was listening to the students, the students were listening to him (reciprocity), but teacher was too directive.
**Critical Thinking in Science – Professional Development Session #1**

**Directions:** In preparation for our first “Critical Thinking” professional development session, please read the article “Don’t Say Anything a Kid Can Say!” by Steven Reinhart (2000). After reading the article, please write a brief response to the following questions. We will begin our professional development session with a group discussion of the article and your responses.

1. How do you define critical thinking?

2. Which strategies identified by Reinhart promote the students’ use of critical thinking skills? List them below.

3. Brainstorm ways in which you have utilized Reinhart’s strategies in your own classes. List some of them below.

4. Are there other “critical thinking” strategies not discussed by Reinhart that you sometimes use in your classes? If so, list them below.

5. Reflect on your practice and the strategies discussed by Reinhart. How might you adapt your instruction to more effectively foster your students’ critical thinking development?
Critical Thinking PD Workshop #2

Sample Video Lessons & Reflection Questions

Sample Lesson #1: “Carbon Cycling: Create Your Own Biology Lab”

- Reflection questions:
  
  o Identify the inquiry components of the lesson: engage, explore, extend, explain.

  o Which components of the lesson do you believe most effectively foster critical thinking development?

Sample Lesson #2: “Introduction to Project-Based Learning Process”

Sample Lesson #3: “Five Keys to Rigorous Project-Based Learning”

- Reflection Questions:
  
  o In what ways does the project-based learning approach incorporate the key ingredients of critical thinking instruction (authentic, dialogue, & mentoring) and inquiry (engage, explore, extend, explain)?

  o What is the role of the teacher in an inquiry- or project-based learning environment?
Critical Thinking PD Workshop #3

Sample Video Lessons & Reflection Questions

Sample Lesson #1: “Energy & Matter Across Science Disciplines”
Sample Lesson #2: “Using Engineering Design in the Classroom”

- Reflection questions:
  - Which components of the lessons foster critical thinking development?
  - In what ways does the problem-based learning approach incorporate the key ingredients of critical thinking instruction (authentic, dialogue, & mentoring)?
  - How do the teaching/learning approaches utilized in these lessons differ from more traditional teaching/learning approaches?
  - What is the role of the teacher in each of the lessons?
  - In what ways does PBL overlap with inquiry-based learning?
**Critical Thinking PD Workshop #4**

**Part I: Reflection and Discussion on Problem-Based Lessons**

1. In what ways did your lesson incorporate problem-based learning or other critical thinking strategies? Did the lesson incorporate any critical thinking concepts (i.e., elements of thought; universal intellectual standards)? If so, how did the lesson incorporate these concepts?

2. After reflecting on your lesson and the RTOP feedback, what components of the lesson do you believe best supported the students’ critical thinking development?

3. After reflecting on the lesson and the RTOP feedback, how would you change your lesson in the future to better support students’ critical thinking?

4. What were the greatest challenges to aligning your lesson with critical thinking practices?

5. After the observation experiences thus far, how have your views about critical thinking instruction changed? What questions or concerns do you still have about critical thinking instruction?
Critical Thinking PD Workshop #4

Part II: Reflection and Discussion on Critical Thinking Assignments

1. Discuss how the assignment incorporated the universal intellectual standards, elements of thought, problem-based learning, inquiry-based learning, and/or other tasks that promoted the use of higher-order cognitive skills.

2. Based on the students’ performance (using the “Critical Thinking Grid”), how effective was the assignment in promoting the students’ use of critical thinking skills?

3. Discuss the different ways in which the assignments fostered the students’ use of critical thinking. What components of the assignment do you believe most effectively fostered the students’ critical thinking?

4. Compare the student work samples shared by your peers. What evidence of critical thinking is apparent in the student work samples?

5. How might you change the assignment in the future to encourage the students’ increased application of critical thinking skills? How could you adapt this assignment for other subjects or units?

6. Discuss the aspects of the assignment process that you found to be most challenging (e.g., the design process, the implementation process, the grading/evaluation process, etc.). What might you do differently in the future to address these challenges?
Appendix D

Teacher Survey: Multivariate Analyses of Participants’ Critical Thinking Knowledge & Pedagogical Beliefs

### Between-Subjects Factors

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b. R Squared = .343 (Adjusted R Squared = .124)
c. Computed using alpha = .05

**Teacher Survey: Multivariate Analyses of Participants’ Critical Thinking Knowledge**

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- R Squared = .002 (Adjusted R Squared = -.088)
- R Squared = .133 (Adjusted R Squared = .055)
- R Squared = .176 (Adjusted R Squared = .101)
- R Squared = .000 (Adjusted R Squared = -.091)
- R Squared = .123 (Adjusted R Squared = .043)
- R Squared = .127 (Adjusted R Squared = .047)
- R Squared = .053 (Adjusted R Squared = -.033)
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**Teacher Survey: Multivariate Analyses of Participants’ Pedagogical Beliefs**

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a. R Squared = .048 (Adjusted R Squared = -.038)
b. R Squared = . (Adjusted R Squared = .)
c. R Squared = .016 (Adjusted R Squared = -.073)
d. R Squared = .118 (Adjusted R Squared = .038)
e. R Squared = .594 (Adjusted R Squared = .558)
f. R Squared = .146 (Adjusted R Squared = .068)
g. R Squared = .002 (Adjusted R Squared = -.089)
h. R Squared = .480 (Adjusted R Squared = .433)
Course Evaluations: Univariate Analyses

**Between-Subjects Factors**

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**Descriptive Statistics**

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**Tests of Between-Subjects Effects**

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^b. R Squared = .026 (Adjusted R Squared = .017)
b. Computed using alpha = .05

**Critical Thinking Assignments: Multivariate Analyses**

### Between-Subjects Factors

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325
### Critical Thinking Assignments: Linear Regression

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- **a. Predictors:** (Constant), Time Point
- **b. Dependent Variable:** Treatment CT Score

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a. R Squared = .000 (Adjusted R Squared = -.005)
b. R Squared = .086 (Adjusted R Squared = .081)
c. R Squared = .005 (Adjusted R Squared = .000)
d. Computed using alpha = .05
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a. Dependent Variable: Treatment CT Score  
b. Predictors: (Constant), Time Point

### Coefficients

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a. Dependent Variable: Treatment CT Score

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a. Dependent Variable: Treatment CT Score

### Model Summary

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a. Predictors: (Constant), Time Point  
b. Dependent Variable: Control CT Score

### ANOVA

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<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
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</thead>
<tbody>
<tr>
<td>1 Regression</td>
<td>1.402</td>
<td>1</td>
<td>1.402</td>
<td>.113</td>
<td>.737b</td>
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<tr>
<td>Residual</td>
<td>2241.516</td>
<td>181</td>
<td>12.384</td>
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<tr>
<td>Total</td>
<td>2242.918</td>
<td>182</td>
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</table>

a. Dependent Variable: Control CT Score  
b. Predictors: (Constant), Time Point
### Coefficients

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
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<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>17.591</td>
<td>.683</td>
<td>25.758</td>
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<td></td>
<td>Time Point</td>
<td>.108</td>
<td>.320</td>
<td>.025</td>
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a. Dependent Variable: Control CT Score

### Residuals Statistics

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
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<tbody>
<tr>
<td>Predicted Value</td>
<td>17.70</td>
<td>17.91</td>
<td>17.80</td>
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<tr>
<td>Residual</td>
<td>-7.806</td>
<td>9.301</td>
<td>.000</td>
<td>3.509</td>
<td>183</td>
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<tr>
<td>Std. Predicted Value</td>
<td>-1.194</td>
<td>1.261</td>
<td>.000</td>
<td>1.000</td>
<td>183</td>
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<tr>
<td>Std. Residual</td>
<td>-2.218</td>
<td>2.643</td>
<td>.000</td>
<td>.997</td>
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</table>

a. Dependent Variable: Control CT Score

### RTOP Observation Data: Univariate Analyses

#### Between-Subjects Factors

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
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<tbody>
<tr>
<td>1</td>
<td>8</td>
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<tr>
<td>2</td>
<td>5</td>
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### Descriptive Statistics

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<th>Group</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>74.13</td>
<td>7.259</td>
<td>8</td>
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<tr>
<td>2</td>
<td>43.80</td>
<td>18.780</td>
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<tr>
<td>Total</td>
<td>62.46</td>
<td>19.599</td>
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## Tests of Between-Subjects Effects

**Dependent Variable:** PostRTOP

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<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Noncent. Parameter</th>
<th>Observed Power³</th>
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<tbody>
<tr>
<td>Corrected Model</td>
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<td>2</td>
<td>1653.234</td>
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<td>.002</td>
<td>.717</td>
<td>25.380</td>
<td>.976</td>
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<tr>
<td>Intercept</td>
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<td>643.408</td>
<td>4.939</td>
<td>.050</td>
<td>.331</td>
<td>4.939</td>
<td>.519</td>
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<tr>
<td>PreRTOP</td>
<td>476.912</td>
<td>1</td>
<td>476.912</td>
<td>3.661</td>
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<td>.409</td>
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<tr>
<td>Group</td>
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<td>2184.419</td>
<td>16.76</td>
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<tr>
<td>Error</td>
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<td>Corrected Total</td>
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</tbody>
</table>

a. R Squared = .717 (Adjusted R Squared = .661)

b. Computed using alpha = .05
MOLLY A. MACEK  
1580 Dellsway Road  
Towson, MD  21286  
(443) 286-9773  
mawilcox01@aol.com

ACADEMIC BACKGROUND

Doctor of Education  
Specialization: 21st Century Education  
Johns Hopkins University – Baltimore, Maryland

Master of Arts in Teaching, Secondary Biology Education  
Johns Hopkins University – Baltimore, Maryland

Bachelor of Science  
Major: Biology  
Georgetown University – Washington, DC

PROFESSIONAL EXPERIENCE

Notre Dame Preparatory School, Towson, MD  
2012 – Present  Science Department Chairperson  
2005 – Present  High School Science Teacher

Academic Roles

• Serve as the Science Department Chair and voting member on the Academic Council.
• Mentor students in Science and Humanities academic programs.
• Observe and evaluate teachers’ classroom practice to support their professional growth.
• Develop and lead research-based professional development experiences to encourage 21st century teaching practices.
• Collaborate with educators to develop interdisciplinary learning opportunities.
• Integrate technology and reform-oriented practices to enhance student learning outcomes.
• Coordinate medical internship and science service learning opportunities for students.
• Manage the Science Department budget and decide necessary department appropriations.
Leadership Roles
2017 – Present  Moderator, Women in Medicine Club
2012 – Present  Chair, Science Department
2009 – Present  Chair, Green School Committee
2006 – 2016  Moderator, Environmental Club
2008 – 2009  Coach, Club Lacrosse
2006 – 2007  Moderator, Student Council
2006 – 2007  Coach, Middle School Tennis

ADDITIONAL EXPERIENCE
Johns Hopkins University, Department of Neurology, Baltimore, MD
2001 – 2005  Laboratory Coordinator, Cutaneous Nerve Laboratory

The Gillette Company, Department of Microbiology, Boston, MA
2000 – 2001  Laboratory Technician

COMMUNITY EXPERIENCE
Immaculate Heart of Mary Church, Baltimore, MD
2017 (Summer)  Volunteer Instructor, Vacation Bible School
2016 – Present  Volunteer Instructor, Children’s Liturgy of the Word

Sursum Corda Youth Reading Program, Washington, DC
1999 – 2000  Volunteer Reading Tutor

Faith United Methodist Church, Rockville, MD
1996  Volunteer Instructor, Vacation Bible School

PROFESSIONAL DEVELOPMENT/CONFERENCES
- Presenter, 2017 MAEA Conference – Medical Illustration as an Interdisciplinary Approach to Enhance Learning in Science and Art
- “Preparing Students for Advanced Placement Environmental Science” (Goucher College, 2013)
- “Integrating Technology in the Science Classroom” (CaseNEX, 2012)
- “Your Schoolyard to the Bay: A Green Schools Experience” (Chesapeake Classrooms Teacher Education Program, 2009)
- “Addressing Student Learning Styles & Differences Using Technology” (NDP, 2009)
- Professional development workshops on educational technology integration (NDP, 2005-present)
SELECTED ACCOMPLISHMENTS

- Led intra- and inter-departmental professional development workshops on 21st Century learning practices including flipped learning and critical thinking instruction.
- Facilitated the development of Notre Dame Preparatory (NDP) School’s STEAM program.
- Founded NDP’s Green School Committee and completed the Maryland Green School certification process.
- Spear-headed and successfully managed NDP’s single-stream recycling program.
- Coordinated NDP’s annual community-wide electronics fundraiser.
- Awarded a grant from the Chesapeake Bay Trust for planting 50 trees on NDP’s campus.